The Bartlett School of Graduate Studies

Refurbish or Rebuild?

A review of the existing housing stock in Great Britain

by

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12 September 2008

A Dissertation submitted in part fulfilment of the Degree of Master of Science Built Environment: Environmental Design and Engineering

ACKNOWLEDGEMENTS

Thanks to my tutor Dr Mark Barrett for his support and encouragement. Also many thanks to Mark Schroeder for his comments.

Thank you to Elmhurst Energy Systems to providing me with a tutorial license of SAP 2005 software.

Abstract

The existing housing sector is responsible for approximately 30% of the total carbon emissions emitted in the UK. In view of the predicted dangers of climate change, the UK Government is committed to reducing carbon emissions by 60% over 1990 levels by 2050. This means that the existing housing stock must improve energy efficiency to achieve low-carbon performance. This can be achieved by either refurbishing or rebuilding homes that perform below regulatory standards.

This dissertation seeks to answer the question of whether it is better to refurbish or rebuild all types of dwellings. The dissertation is divided into two parts.

Part A analyses energy demand and energy supply for both refurbished and new dwellings. Chapter A1 uses various models to analyse the cost and energy performance of various dwelling types to establish where savings are best made. The chapter establishes the range of energy-efficiency measures that could be used on refurbished dwellings and models new dwellings by demolishing and rebuilding existing homes to 'best-practice' standards. Part A concludes that refurbished dwellings deliver significant cost and carbon savings regardless of dwelling type. Refurbished buildings perform nearly to the same efficiencies as new build in terms of operational cost and carbon savings. New dwellings on the other hand require significant capital expenditure and result in high embodied energy. A theoretical demonstration of carbon reductions from energy supplies in Chapter A2 illustrates that replacing fossil fuels with renewables for electricity supply can achieve significant reductions in carbon emissions which could further improve the carbon efficiency of dwellings.

Part B discusses issues that influence the process of implementing energy saving measures in dwellings. The main findings result in the importance of putting appropriate long-term regulatory and policy frameworks in place to ensure adequate reductions can be made without impacting on heritage and to protect households from fuel poverty.

The dissertation concludes that refurbishment is preferred over new build dwellings. Energy and carbon savings can be achieved at a much lower cost, in a shorter period of time and by utilising lower embodied energy. This conclusion is certainly evident when renewables are employed. Albeit, the overall success is largely dependant on the speed and scale of uptake by households, councils and industry, therefore, in order to reduce carbon emissions, the Government needs to sponsor change through education, policy, regulation and funding.

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Introduction

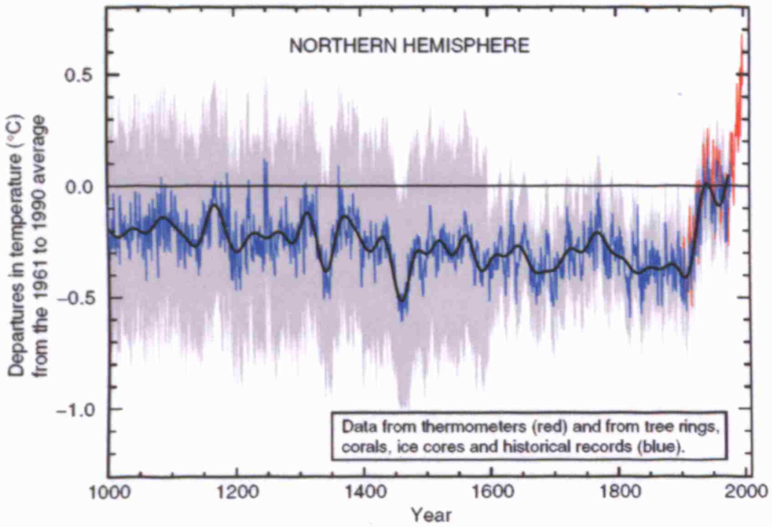
In the age of climate change the UK Government has set national obligations to reduce carbon emissions in all sectors of the built environment. This commitment has resulted in the need to improve dwellings to a higher energy-efficiency in order to reduce carbon emissions in the future.

This dissertation analyses the housing stock in Great Britain (GB). The objective is to answer the question of whether it is better to refurbish existing dwellings or replace them with new build. The dissertation explores two paths of decision making: firstly quantifiable results, which evaluates energy and cost performance through various calculation models and reviews criteria along with suggestions for improving dwellings; and secondly non-quantifiable decisions, which reviews policy, funding streams and buildability. Both paths are considered equally in order to provide a holistic answer to whether it is better to refurbish or rebuild existing dwellings.

Background

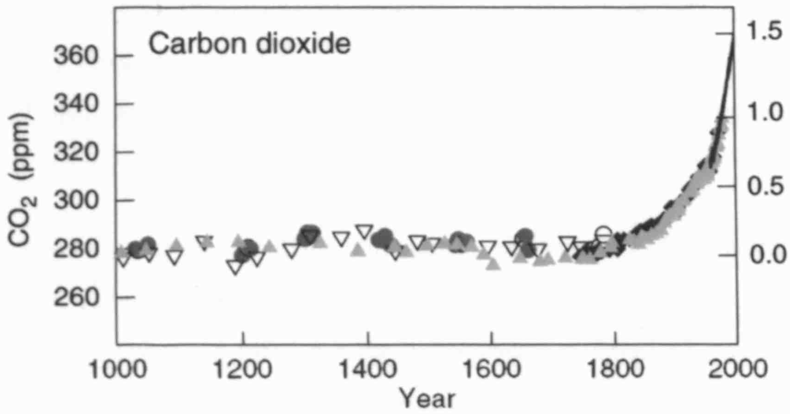
The world today is faced with a major challenge called climate change. Greenhouse gas (GHG) emissions and temperatures have risen at an alarming rate since the early 1900s to levels beyond anything ever seen in human history. The temperature rise has been confirmed by the Intergovernmental Panel on Climate Change (IPCC) in the 2001 Assessment Report (IPCC 2001), which is summarised by their 1,000-year 'hockey stick' graph. The graph clearly illustrates that temperatures have risen sharply by almost 1° C over the last hundred years.

Figure 1: 'Hockey stick' graph, average world temperatures (IPCC 2001, p.3)



The atmospheric concentration of the most abundant GHG is carbon dioxide (CO_2), which has risen exponentially from pre-industrial levels of 280 ppm in 1750 to 379 ppm in 2005 (IPCC 2007). With all other GHGs added it becomes CO_2 equivalent (CO_2e) values, which amount to 430 ppm (Stern 2006).

Figure 2: Average world carbon dioxide levels (IPCC 2001, p.6)



It is now universally accepted that the increase of atmospheric GHG in the environment and the subsequent rise in temperature are man-made due to the growth in human population and industrialization.

Burning fossil fuels to produce energy generates large amounts of CO_2. Developed and developing countries rely heavily on energy services from fossil fuels despite limited supplies.

The UK Government produced the Stern report in 2006 to investigate the implications of climate change. The dissertation clearly demonstrates that '*the risks of the worst impacts of climate change can be substantially reduced if greenhouse gas levels in the atmosphere can be stabilised between 450 and 550ppm CO_2e*' (Stern 2006, p.vii). However, levels are currently still increasing by 2 ppm per year and action to mitigate further rise is required immediately (Stern 2006).

To counteract the dangers of climate change, the UK Government released the Energy White Paper in 2003 with a legally binding framework to reduce overall carbon emissions to stabilise atmospheric CO_2e concentration at 550 ppm (DTI 2003). For the housing sector this means a reduction of 60% by 2050 over 1990 levels.

However, recent research ('Home Truths' Boardman 2007, 'How Low' Moore 2008) concludes that a 60% target is not sufficient to avoid irreversible damage from climate change. The research recommend that GHG emissions must be stabilised at 450 ppm CO_2e which requires all developed countries to achieve an 80% target by 2050 over 1990 levels. These amendments are in the Draft Climate Change Bill which is currently in the House of Commons for consideration (House of Commons 2007).

The UK contributes approximately 2% to global man-made CO_2 emissions. In 2006, these emissions equated to 152 million tonnes of carbon (MtC) (Defra 2008). The residential sector collectively emitted 41.7 MtC, an equivalent of nearly 30% of total UK carbon emissions. This means that the domestic emissions would need to fall to 17 MtC/yr by 2050 to meet the Government's overall 60% carbon emissions reduction (CLG 2006b) or to 8 MtC/yr if an 80% target must be achieved, assuming a proportional reduction across all sectors.

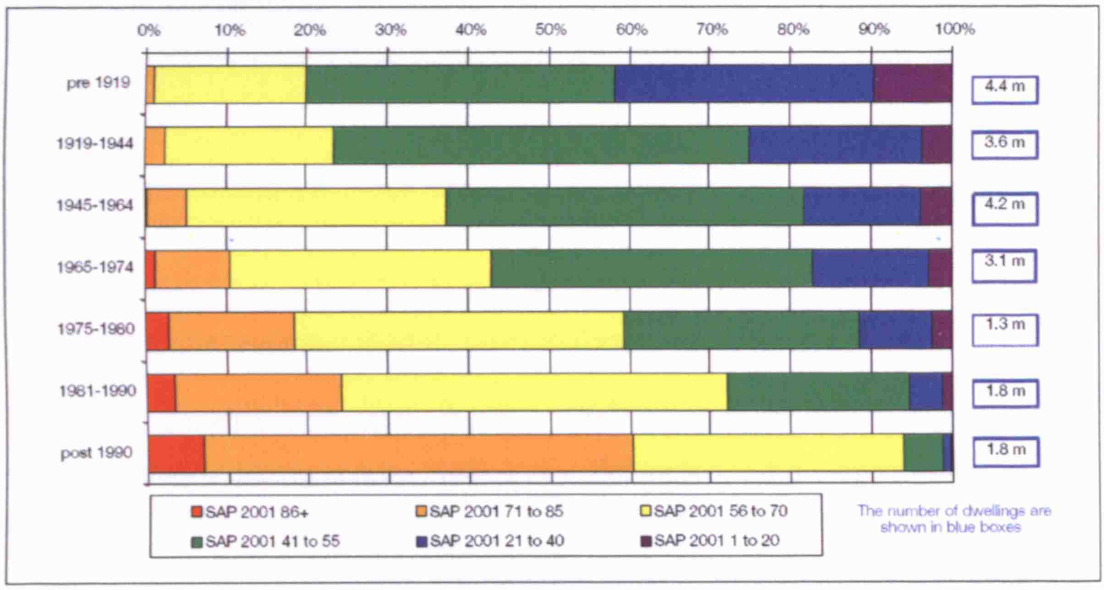
The construction industry has increased the profile of sustainability in the last few years, but emphasis has been placed on new build rather than the existing building stock. This emphasis has stimulated investment in innovative projects such as the '60K Home', the 'Carbon Challenge' and the Government's recent target of constructing 3 million new energy efficient homes (many in Eco-towns) by 2020. Although this is the right direction to be heading in, these headline grabbing tokens blind us to the fact that the real challenge lies within the majority of existing buildings; especially the poor quality housing stock.

Based on current forecasts, the housing stock that exists today will represent around 75% of all properties in 2050 (Boardman 2007). This means that carbon emissions from existing and future housing will need to be drastically reduced to meet current Government targets. The Energy White Paper recognises that energy efficiency is the '*cheapest, cleanest and safest way*' of reducing carbon emissions (DTI 2003, p.16).

Statutory building regulations and standards have improved the energy efficiency of new buildings considerably in the last years. However, new build housing only represents around 1% of the total housing stock (CLG 2006b). Of the 25 million homes that exist today, 21 million were built before 1980. The relationship between the age of a dwelling and its energy performance is illustrated in Figure 3, which is based on a recognised Standard Assessment Performance (SAP) rating that measures the heating and fabric efficiency of buildings on a scale from 0 -100, with 100 being most efficient. The diagram below illustrates that existing homes constructed before 1980 have very low SAP ratings and dominate the total number of dwellings.

On average, the existing housing stock has a SAP rating of only 51 points (Shorrock 2003). Around 18% of the total dwelling stock has inadequate thermal performance and only 6% complies with modern building standards (BRE 2008b).

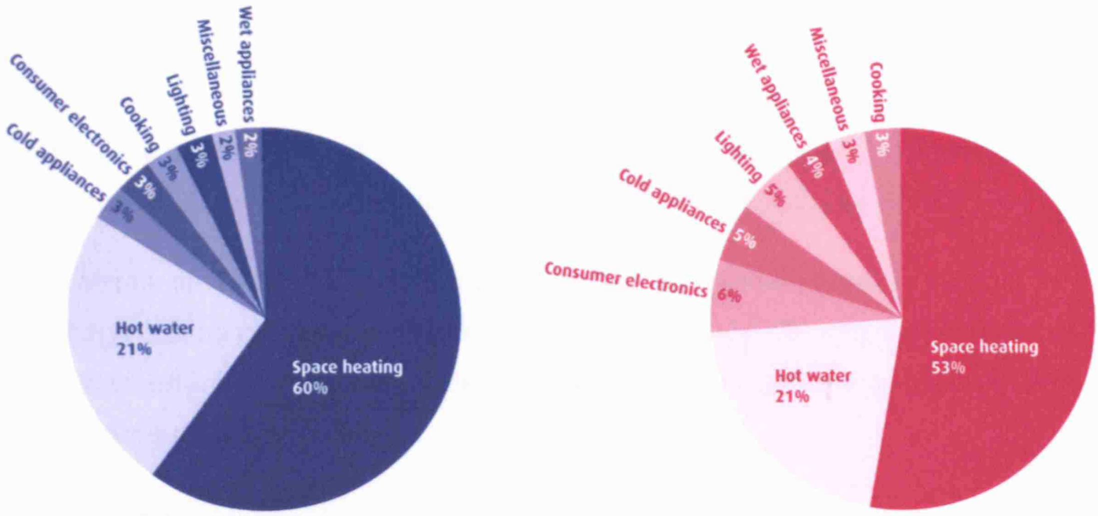
Figure 3: Profile of energy performance in existing dwelling stock (CLG 2006b, p.5)



Based on English House Condition Survey (EHCS) 2004, DCLG

Figure 4 represents the distribution of the UK's household energy consumption and carbon emissions. Space and hot water heating is responsible for 81% of the total energy consumption and 74% of carbon emissions because the existing housing stock in the UK is badly insulated; thus wasting energy. According to recent studies, the delivered energy consumption for space heating in the UK is nearly twice that of Nordic countries (Boardman 2007). This demonstrates that urgent focus on energy efficiency is required.

Figure 4: Household energy consumption and CO_2 emissions by end use (SDC 2006, p.27f)



Household energy consumption by end use

Household carbon emissions by end use

Although the existing stock has already seen some improvements in energy efficiency for space heating in recent years, energy consumption is still rising, because houses are getting larger and residents are living in warmer homes due to modern expectations of thermal comfort (Boardman 2007).

To tackle the inefficiencies of the existing housing stock, the Government is taking steps towards reducing energy-inefficiency. For instance the Government announced that *'by the end of the next decade, all householders will have been offered help to introduce energy-efficiency measures with the aim that, where practicably possible, all homes will have achieved their cost-effective energy potential'* (HM Treasury 2007, p.11).

However, recent reports ('How low' Moore 2008, 'Home Truths' Boardman 2007) indicate that carbon savings are vital to delivering the Government's targets but that the existing policies will be insufficient for a 60-80% reduction in CO_2 by 2050. Therefore, further activities and investments in refurbishments of existing homes and low-and-zero-carbon (LZC) technologies are required (Killip 2008).

Aim and methodology

The energy performance of the existing housing stock is crucial to achieving the Government's commitment of reducing carbon by 60% to 80% by 2050.

The overall aim of this dissertation is to answer the question whether existing dwellings can be refurbished to make them more energy-efficient, or whether it is more cost-effective and more efficient to demolish and replace the dwellings with more energy-efficient homes.

To analyse how homes can become more energy-efficient, it is important to understand the energy requirements that result from the energy demand and supply in dwellings.

Homes require energy supplies to provide comfort and to perform tasks such as the provision of heating, hot water and electricity. Energy demand is driven by the thermal performance of the building envelope and the efficiency of the heating system but also by the demand from electrical appliances, lighting and cooking.

The demand for energy has increased over the years because of modern lifestyles. For instance, residents are continuously adding more electricity-hungry gadgets to their homes. The demand from electrical appliances and cooking is dependant on lifestyle choices of the occupants rather than the dwelling's performance, which is not within the scope of this dissertation. Hence, this dissertation only factors in the 'physical' parameters of houses in GB and their impact on energy-efficiency, which includes the building fabric, space and hot water heating and electricity for lighting.

To make homes more energy-efficient, the use of energy and its carbon content must be reduced. How this can be achieved is dependant on a range of factors.

This dissertation is divided into two parts to analyse these factors independently and review the implications of each to draw a conclusion.

Part A reviews the existing building stock quantitatively based on cost and energy performance of either refurbishing or replacing various building types in context to energy demand and supply.

Part B assesses non-quantified factors because the decision making of whether to refurbish or replace existing homes cannot purely be determined by the performance of cost and energy efficiency alone. These factors may assist or limit energy-efficiency options for existing buildings. Part B also suggests implementation opportunities on how further carbon reductions could be achieved.

PART A

Quantified results

Part A focuses on all the aspects that can be 'measured' such as the economic impact from fuel costs and carbon emissions that arise from energy demand in dwellings and capital costs from the application of improvement measures in refurbishments and new construction. These measurements can assess the cost-effectiveness and carbon savings by building types and for the whole housing stock.

The carbon reductions and economic performance which energy efficiency can achieve depend on the carbon content of the supplied fuels. Over the years, the type of fuels and hence their carbon contents will change and influence the economic performance of energy supplies. Part A discusses these variables in order to review alternative technologies to fossil fuels.

To find out whether existing buildings should be refurbished or replaced, several calculation models are established so that the results can be reviewed based on energy and cost performance of the dwellings.

There are five calculation models looking at the average energy performance of the housing stock in Great Britain (GB). Models 1 to 4 focus on the demand side of energy whereas model 5 considers the supply side of energy:

Demand side:

- Model 1: Operational cost and energy performance
- Model 2: Capital cost and savings
- Model 3: Primary energy consumption
- Model 4: Energy requirements of the total housing stock in GB

Supply side:

- Model 5: Considerations for LZC technologies

The following chapters explore the models to discuss the aspects for the demand and the supply requirements of energy in GB homes.

Demand side of dwellings

Part A1 is configured to establish three scenarios for energy performance of existing, refurbished and new dwellings:

- Scenario 1: Present condition of existing dwellings
- Scenario 2: Refurbished dwellings with applied energy-saving improvements and
- Scenario 3: Corresponding new build dwellings if the existing were to be replaced.

Housing types in GB come in all types and sizes. To simplify the range of dwelling types the total existing housing stock is broken down into five predominant categories:

- Semi detached houses
- Terraced houses
- Flats
- Detached houses
- Bungalows

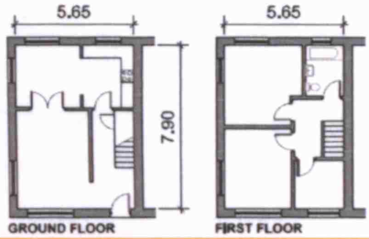
Figure 5 illustrates typical images and floor plans for each represented house type and provides a general breakdown of all existing housing stock in GB in 2001, the year in which coherent data was available from research documents.

Figure 5: Typical building types of the housing stock

SEMI-DETACHED

Areas:

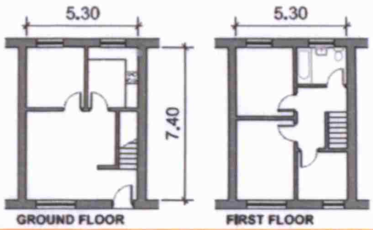
Total:	89.0 m2
Ground Floor:	44.5 m2
Walls:	97.5 m2
Roof:	44.5 m2
Windows:	17.0 m2
Storeys:	2
Perimeter:	19.5 m



MID TERRACE

Areas:

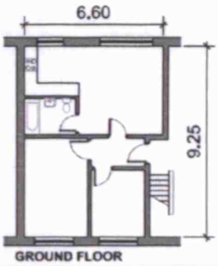
Total:	79.0 m2
Ground Floor:	39.5 m2
Walls:	50.0 m2
Roof:	39.5 m2
Windows:	16.0 m2
Storeys:	2
Perimeter:	10.0 m



FLAT

Areas:

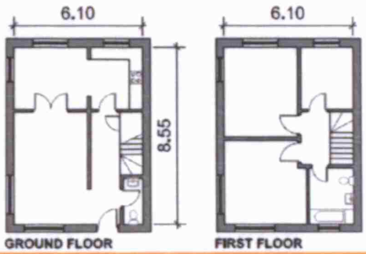
Total:	61.0 m2
Ground Floor:	0.0 m2
Walls:	31.7 m2
Roof:	0.0 m2
Windows:	7.0 m2
Storeys:	1
Perimeter:	13.2 m



DETACHED

Areas:

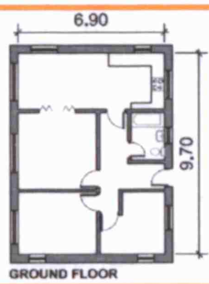
Total:	104.0 m2
Ground Floor:	52.0 m2
Walls:	146.0 m2
Roof:	52.0 m2
Windows:	19.0 m2
Storeys:	2
Perimeter:	29.2 m



BUNGALOW

Areas:

Total:	67.0 m2
Ground Floor:	67.0 m2
Walls:	79.7 m2
Roof:	67.0 m2
Windows:	13.8 m2
Storeys:	1
Perimeter:	33.2 m2



NOTE: The images represent typical housing types but are not the ones specifically modelled.

Table 1 illustrates that semi-detached and terraced houses are the most dominant building type - representing more than a quarter of all dwellings each. Flats and detached houses represent 19% and 16% respectively. Bungalows are less common, which only represent 8% of all housing. Although detached houses represent only 16% of all dwellings, their larger external surface area increases their overall representation to almost 26% of all housing.

Table 1: Existing housing stock of GB

Existing Housing Stock of Great Britain in 2001							
		Semi-Detached	Mid Terrace	Flat	Detached	Bungalow
Number Dwellings (Total 24,422,000) [1]	(1,000s)	6,936	6,766	4,639	3,956	2,051
% of Housing Stock [1]	%	28.4%	27.7%	18.9%	16.2%	8.4%
Household Occupants [2]		3	2-3	2	3	2
Average Floor Area per Dwelling [3]	m^2	89	79	61	104	67
Total Floor Area	m^2	617,304	534,514	282,979	411,424	137,417
Total External Surface Area	m^2	1,435,752	1,008,134	185,560	1,079,988	473,781

Source [1] Shorrock 2003 [2] Lowe 2008 [3] EST 2000

Model 1: OPERATIONAL COST AND ENERGY PERFORMANCE

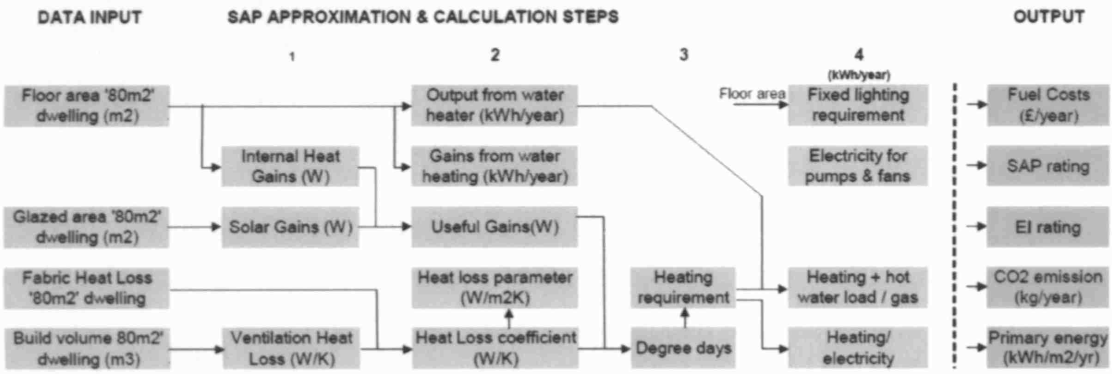
Model 1 measures annual operational costs for energy used and the resulting carbon emissions in a fossil fuel scenario. The aims are to compare improvements of refurbished against equivalent new build dwellings in terms of fuel efficiency of the heating system and thermal efficiency of the building fabric and to analyse how refurbished homes vary in their performance for different building types. To model this scenario the Government's Standard Assessment Procedure (SAP) is used, because it is an approved system for calculating costs, energy requirements and carbon emissions.

The model employs version 13 of Elmhurst's approved SAP Design software, which is based on the worksheet version 9.80 of SAP 2005 (Defra 2005).

SAP considers the energy performance of dwellings per unit floor area and is represented as an energy cost rating (SAP rating) and an environmental impact rating based on CO_2 emissions (EI rating).

The SAP rating examines the cost-efficiency and the EI rating calculates carbon saving benefits based on the annual CO_2 emissions arising from space and water heating, ventilation and lighting as shown in Figure 6. Emissions saved by energy generation technologies can be modelled with this software. However, this will be discussed separately in Chapter A2.

Figure 6: SAP calculation flow chart (Mueller 2006, p.16)



Both ratings are adjusted for floor area to be independent of dwelling size for a given form so that all houses can be compared equally on a scale of 1-100, with 100 being most efficient.

The data input in SAP is based on assumptions (listed in Figure 5), which typically characterise housing types in GB (Shorrock 2003).

The calculation simulates 'weighted' climate conditions for all dwellings, choosing Sheffield (Midlands) in the geographical centre of GB.

Specific data of a dwelling such as orientation or exposure are modelled with default values as recommended in SAP so that these parameters will not influence the results (SAP 2005).

Further input information for the calculation is described in the following sections covering each scenario of existing, refurbished and new build. Detailed spreadsheets containing the full model data, a typical SAP printout and limiting criteria of the models are attached in Appendix 1-5.

Scenario 1: Present condition of existing dwellings

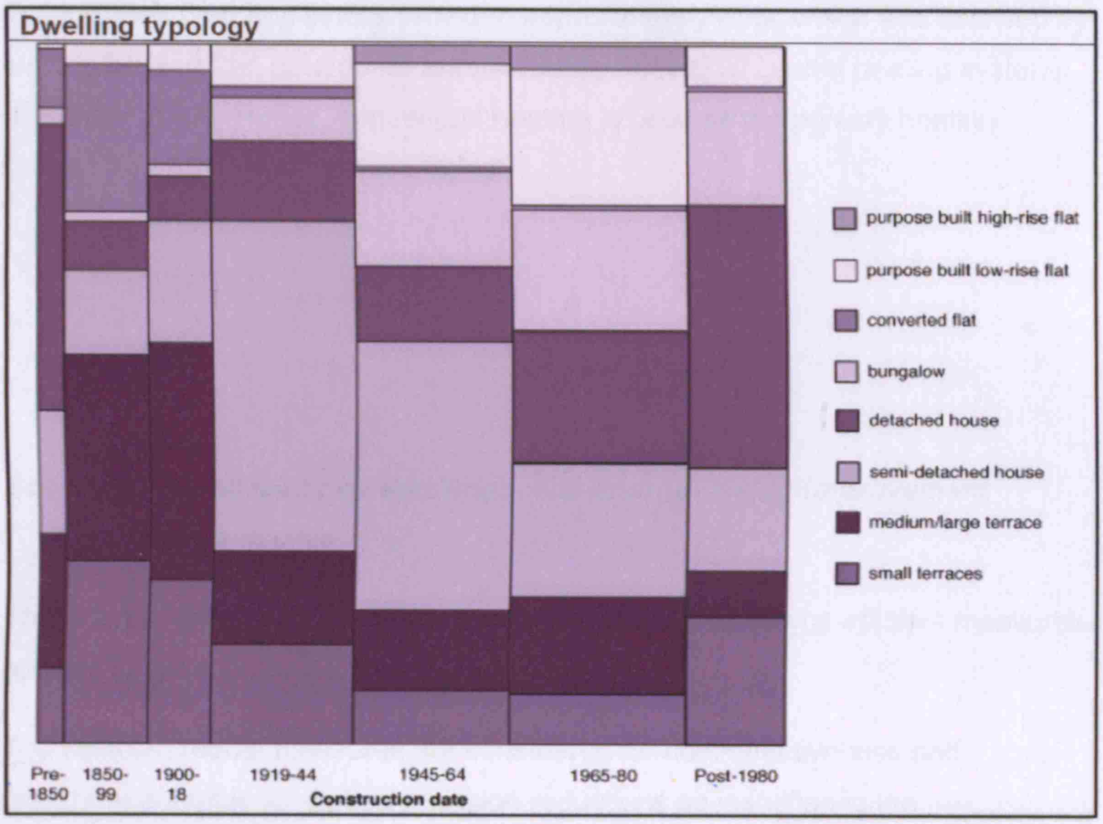
Data is drawn together from various studies and combined in one generic model for existing homes. These include SAP 2005 Appendix S for existing dwellings (SAP 2005), base case data for a programme named 'Fuel Prophet' that has been developed by the Association for the Conservation of Energy (ACE 2006), the 'Domestic energy fact file 2003' by Shorrock and Utley (Shorrock 2003) and information from the Energy Savings Trust (EST 2003).

Existing dwellings employ two main forms of construction: solid and cavity wall, which are strongly related to the age of the dwelling. Before 1930, walls were constructed with solid brick. This type of construction represents approximately 25% of the all existing housing stock. Hence, most of them are not insulated (EST 2000).

After 1930, cavity walls became a common form of construction, because it was a fairly cheap and easy method of insulating a home without any internal space losses or external effects on the façade. A third of all cavity wall homes in GB have cavity insulation installed. Studies have found that cavity wall homes are more likely to have had other energy-saving improvements such as loft insulation or double glazing installed in recent years (Shorrock 2003).

As shown in Figure 7, terraces and semi-detached houses represent approximately 75% of all existing housing stock constructed before 1930. Two types are modelled for each, solid and cavity wall construction, to take into account the difference in performance caused by heat loss.

Figure 7: **Dwelling typology (CLG 1996, p.6)**



U-values shown in Table 2 apply to all existing homes. Flats have a variety of conditions depending on its location within the building. For example, a flat in the middle of the block reduces heat losses, because it has neighbouring properties on all but one or two sides. To simulate flats, an average proportion of top floor, ground floor, end of block and mid-level flats has been modelled.

Table 2: **U-values - Existing**

Existing Dwellings - U-values (W/m^{2}K)			
	Solid Wall	Cavity Wall	Flats
Ground Floor	0.70		0.10
Walls	2.10	1.50	
Roofs	1.00	0.40	0.10
Windows	single 4.80	1/2 double, 6mm 3.10	
External Doors	3.00		

By 2001, approximately 90% of all existing housing stock in GB had central heating. Gas fired appliances provided approximately 80%, which was followed by electric heating that catered for approximately 10% of all central heating systems (Shorrock 2003). Hence, central gas heating is used as the primary heating system for all the modelled scenarios.

Scenario 2: Refurbished dwellings with energy-saving improvement measures

The refurbished scenario models the implementation of energy-efficient measures applied to existing homes.

The selected retrofit measures are considered for cost-effectiveness and maximum potential for carbon emission reductions as identified in the Government's 2007 Budget statement (HM Treasury 2007). These measures include insulation, draught proofing, efficient boilers, heating controls and low energy lighting.

Figure 8 illustrates that the uptake of measures is already along the way but many of them have still a large potential for complete uptake. For example, many homes have loft insulation installed but are insufficient to embrace the full potential of energy savings.

There are several refurbishment guides that have been published by the Energy Savings Trust (EST) and the Sustainable Development Commission (SDC) which assess the current extent of measures that can realistically be applied for improving specifications for a dwelling's performance (EST 2000, EST 2003, SDC 2006). These values are modelled in the SAP calculation.

Figure 8: Market penetration of energy-efficiency measures (Shorrock 2003, p.11)

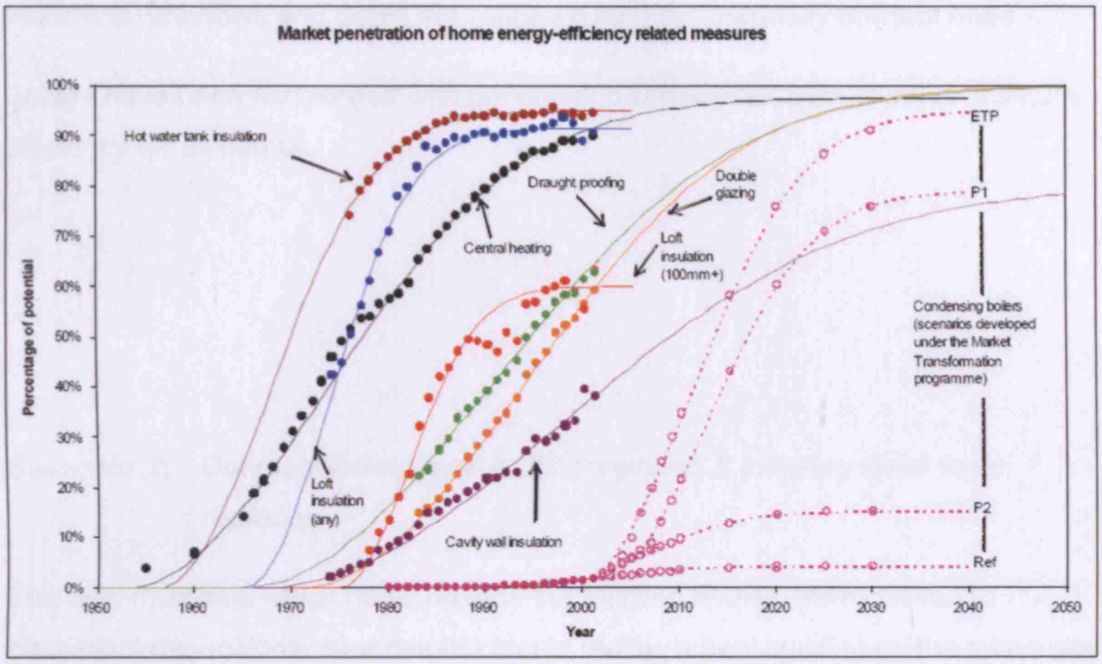


Table 3 shows the improved U-values in comparison to the area-weighted average U-values as prescribed in the Building Regulation Part L1B for the conservation of fuel and power (ODPM 2006). The refurbished dwellings perform equivalent or better after the measures are installed.

Table 3: U-values - Refurbished

Refurbished Dwellings - U-values (W/m^{2}K)		
	Refurbished	AD Part L1B
Ground Floor	0.25	0.25
Walls (solid+cavity)	0.35	0.35
Roofs	0.16	0.25
Windows	1.30	2.20
External Doors	1.00	2.20

To reduce heat loss from dwellings, the thermal efficiency of the building envelope is improved to achieve lower heat transfers, therefore resulting in lower U-values.

Improvements to floors, walls and roofs are achieved by installing (additional) insulation. Windows and doors are replaced by more thermally efficient ones.

Boilers have been exchanged with condensing boilers SEDBUK Band A of 91.2% efficiency for all homes.

Scenario 3: Corresponding new build dwellings if existing ones were replaced

The new dwellings which could replace the existing homes are modelled to equivalent dimensions, floor heights etc. In reality, a new building on the same site would likely be constructed to a different brief. For example, a semi-detached house may comprise several smaller flats on the same footprint and glazed areas would likely be smaller than older homes. However, for a correct one-to-one comparison, the building arrangements in this dissertation have not been modified.

The specification for new build homes corresponds to 'best practice' standards. 'Best practice' standards as set out in the guide 'Building a sustainable future' by the Energy Savings Trust (EST 2006) result in much lower U-values than the minimum required today under Building Regulations AD Part L1A (ODPM 2006).

Table 4: U-values - New build

New Build Dwellings - U-values (W/m^2K)		
	Best Practice	AD Part L1A
Ground Floor	0.20	0.25
Walls	0.20	0.35
Roofs	0.10	0.25
Windows	1.30	2.20
External Doors	1.00	2.20

Better U-values could be achieved under zero-heating or passive house conditions. However, this level will unlikely become part of Building Regulations in the near future and, therefore, a realistic standard is preferred for this calculation.

All dwellings are equipped with whole house mechanical ventilation and heat recovery (MVHR) and are equipped with SEDBUK Band A combi gas condensing boilers with 92.5% efficiency.

Modelling the different building types for the existing, refurbished and new build provides a comparison between SAP and EI ratings that are achieved.

Figure 9 and Figure 10 indicate that the worst performing dwellings are existing dwellings with solid wall construction, which results in a SAP rating of 39 for semi-detached and 45 for a mid-terrace and an EI rating of 34 and 45 respectively. Cavity walls perform better than solid wall construction due to the lower thermal transmittance (U-value) of the building envelope. Cavity wall construction for detached homes and bungalows are lower with 42 and 43 respectively and associated EI ratings of 37 for both. The best performing existing building type is a flat.

Figure 9: Calculated SAP ratings by dwelling type

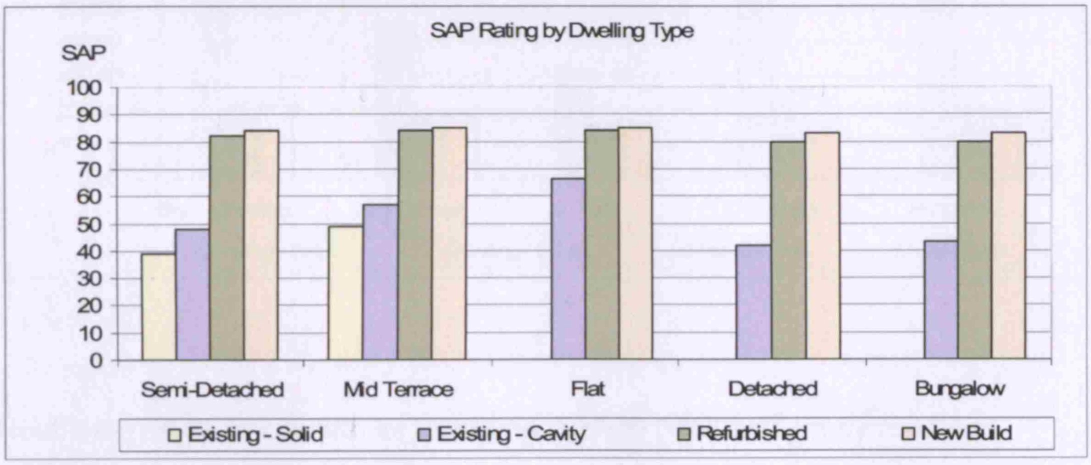
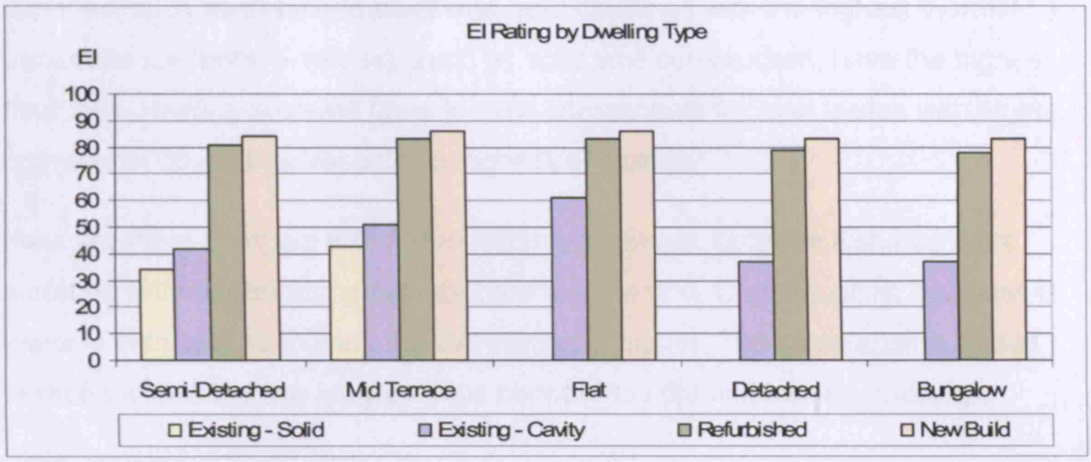
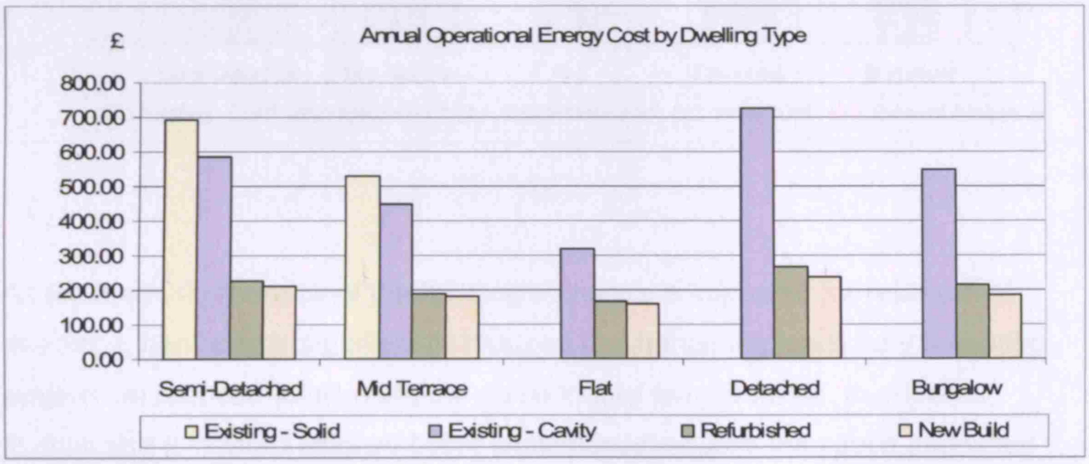


Figure 10: Calculated EI ratings by dwelling type



Because the SAP rating is based on the energy cost to operate the building, the higher the SAP rating the lower the operational cost, i.e. better improvements result in higher cost reductions as seen in Figure 11.

Figure 11: Annual operational energy cost by dwelling type

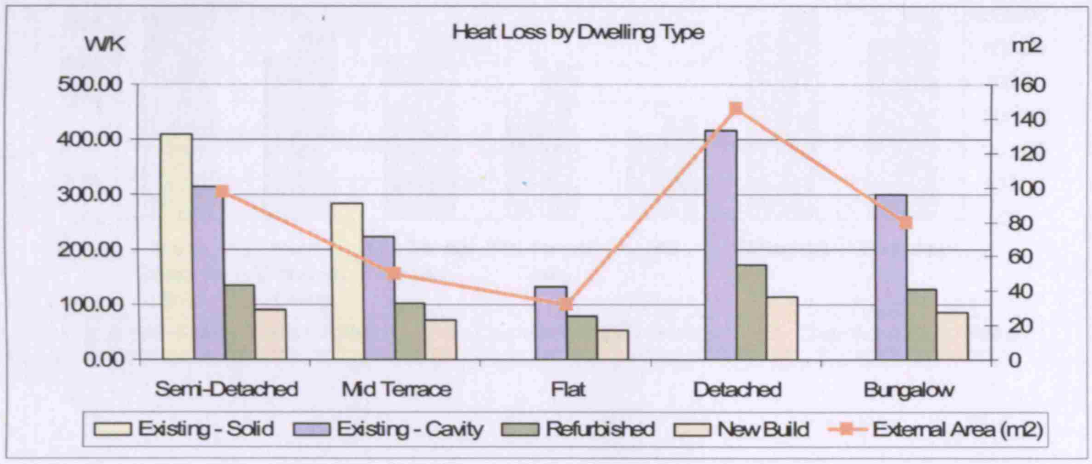


Heat loss results from warm air escaping through gaps and poorly insulated building envelopes. Existing buildings vary greatly in SAP.

It can clearly be seen in Figure 12 that the dwellings with the largest exposed surfaces, such as detached dwellings, and dwellings with the highest thermal transmittance (poor U-values), such as solid wall construction, have the highest heat loss. Heating systems have to over-compensate for heat losses with higher operational costs, thus resulting in poor SAP ratings.

Flats are more compact within the building envelope, because it shares more surfaces with neighbouring flats that are also heated. Consequently, heat loss is lower in flats and as a result the SAP rating is higher. The same applies to mid terraces where the two longest walls connect to adjacent heated dwellings.

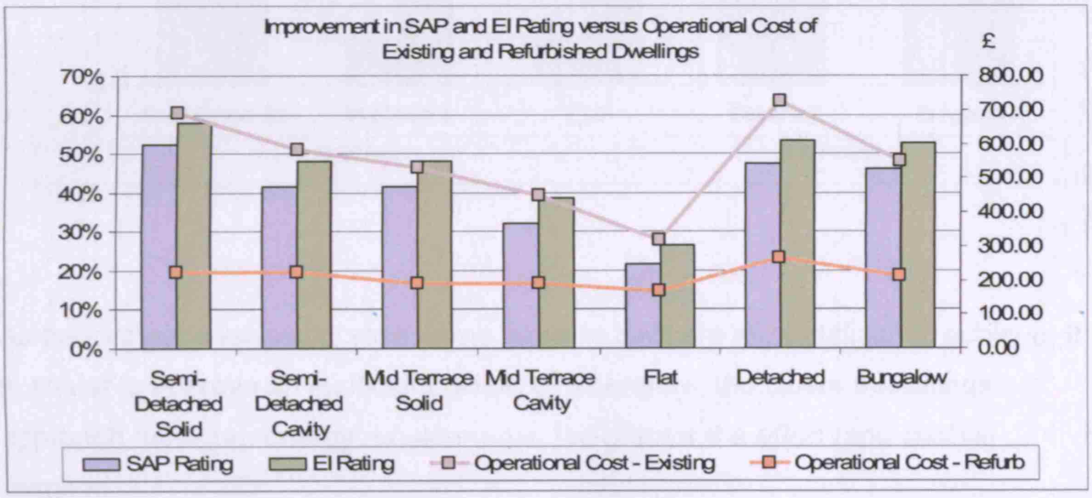
Figure 12: Heat loss by dwelling type



As the thermal efficiency of the building envelope is improved for refurbished dwellings, heat loss is significantly reduced and hence the loads on the heating system are reduced to maintain the same indoor temperatures. In addition, exchanging to a more efficient boiler significantly reduces the space and water heating loads. Combining these two factors can have a large positive impact on the overall ratings. All types of refurbished buildings achieve a very similar result between 80 and 84 for SAP and 78 and 83 for EI ratings. The similarities are due to the fact that heat and ventilation losses are reduced proportionally; therefore, the level of heating loads is similar for all dwelling types.

Figure 13 shows improvements expressed in percentage terms for SAP and EI ratings versus operational costs for existing dwellings and refurbished dwellings. The biggest potential for energy and cost savings is achieved through refurbishment on dwellings that have the highest existing operational costs, mostly resulting from large surface areas and badly insulated building envelopes – especially detached dwellings and bungalows and dwellings with solid wall construction. These types of dwellings have the highest potential for savings.

Figure 13: Improvements and operational cost of existing and refurbished dwellings

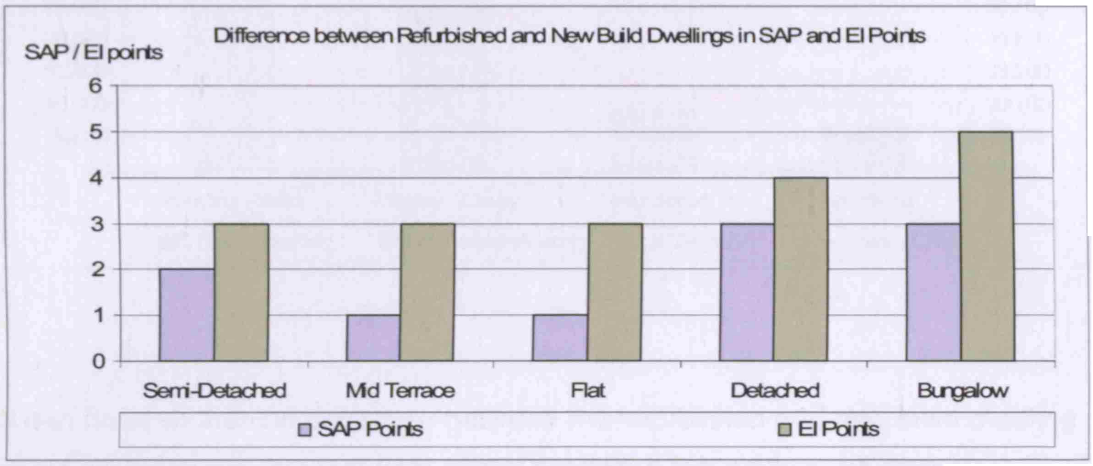


New build dwellings for all building types are not performing significantly better than refurbished dwellings. The ratings range from 83 to 85 for SAP and 83 to 86 for EI ratings. Figure 14 indicates the difference in SAP points between refurbished and new build dwellings. The largest difference in EI rating is only 5 points for bungalows and 3 points in SAP rating for bungalows and detached dwellings.

For the same reasons as refurbished dwellings, the energy requirements for space heating are very low. Therefore, when heat losses have been compensated for and efficient boilers introduced the reduction in energy demands is maximised. Notwithstanding, the results are similar when comparing operational costs and

CO_2 emissions. Refurbished dwellings have slightly lower results because U-values and ventilation losses are not as efficient as new build.

Figure 14: Difference between refurbished and new build in SAP and EI ratings

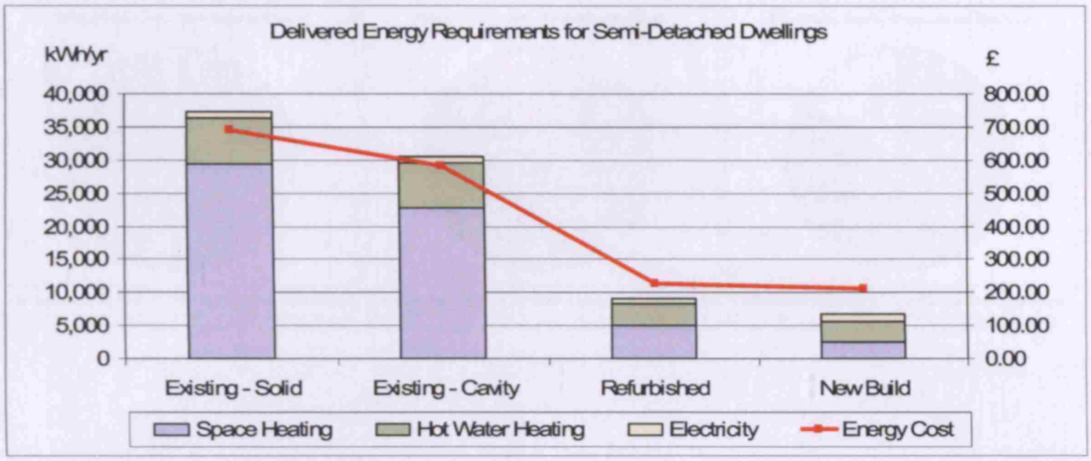


As performance levels improve, large gains in SAP are more difficult to achieve. It is easier to improve an inefficient dwelling. Therefore, the closer the ratings approach minimum energy requirements, the greater the effort (and cost) is required.

To explore where energy savings have been made, Figure 15 shows the composition of space and hot water heating and electricity requirements for a semi-detached dwelling for existing, refurbished and new dwellings.

The figures for semi-detached dwellings are similar to other dwelling types, therefore, only this type is illustrated. It clearly indicates that the largest savings are in space heating requirements as a result of reduced ventilation and heat loss. Savings in hot water energy is a result of installing a more efficient boiler for both refurbished and new build dwellings. Electricity requirements are higher in new build due to the application of MVHR systems even though energy-efficient lighting has been introduced.

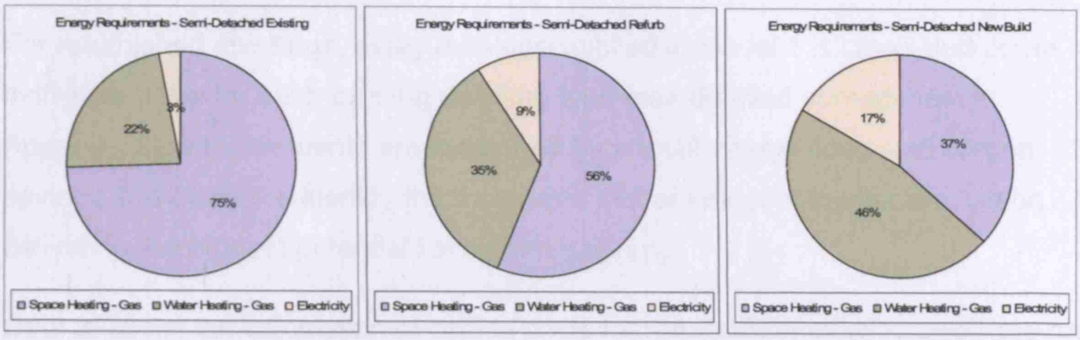
Figure 15: Delivered energy requirements for semi-detached dwellings



It can be seen that the difference between the refurbished and new build dwelling is mainly in the requirement from space heating. It is double in refurbishments compared to new build because thermal bridging and lower U-values in a refurbished dwelling causes higher heat loss. Operational costs for a refurbished dwelling can be reduced by almost 60% and is very close to the operational costs for a new build.

Figure 16 demonstrates that once the space heating requirements are reduced, due to improvements to the building envelope, hot water heating and electricity provision becomes proportionally more significant, e.g. whilst electrical consumption only accounts for 3% in an existing home, it is responsible for 17% in a new build home. The carbon intensity of electricity is currently about 2.5 times higher than gas because it demands much more primary energy for production and distribution. The problem has not got any better, because energy use for lighting and appliances has grown significantly by almost 2% every year (SDC 2006). The focus will shift towards individual (household) behaviour as building thermal performances are improved.

Figure 16: Energy requirements for existing, refurbished and new build



In summary, the SAP ratings illustrate that buildings with poor thermal performing envelopes and mechanical equipment have the worst performance for both energy costs and carbon emissions. Refurbishing buildings can result in high SAP and EI ratings, which is not far off from ratings for new build dwellings. Significant carbon savings can be achieved by raising the energy performance of the worst performing building types.

Although this chapter illustrates that refurbished dwellings have energy efficiency and energy cost performances close to new dwellings that are built to a high specification, it does not compare the capital costs between refurbishment and new build, which will be discussed in the following chapter.

Model 2: CAPITAL COST AND SAVINGS

Refurbished and new build homes are examined for the potential savings that can be made and for the cost-effectiveness of carbon-savings measures for refurbishments.

Refurbishment measures

For refurbished dwellings, every measure applied in Model 1 is calculated on an individual basis for each existing dwelling type (see detailed spreadsheet in Appendix 6). Improvements are measured by annual energy costs and carbon savings and therefore identify the measures that are most cost-effective, whilst delivering the biggest potential for carbon savings.

Data to assist the calculation of capital costs for refurbishing existing dwellings has been obtained from the Energy Savings Trust (EST 2008) and personal telephone conversations with the National Insulation Association (NIA) and private contractors (see Appendix 7).

Taking into account the lifetime and annuitised cost (the annual payment of the total allowance) of the measures at a 7% interest rate, the payback time analyses the cost-effectiveness by return of the initial investment, i.e. which measures offer the biggest potential savings per pound spent.

The lifetime of the measures is capped at 50 years because this is the time before major refurbishments are likely to occur again (EHA 2008). In reality, improved measures, such as insulation, will remain as long as the building does.

To compare the economic benefits involved in the refurbishing of dwellings, it is necessary to recognize the cost-effectiveness and payback time of each measure so that priorities can be placed on achieving the highest carbon savings.

The capital costs for applying all new measures is included in the overall costs, but they do not account for any subsidies that may be obtained.

Figure 17 establishes the cost-effectiveness of each measure based on its capital cost over the achieved carbon savings during its lifetime. The most cost-effective measures are those closest to the zero mark on the positive side. These measures present the biggest potential carbon savings for every pound spent on the overall investment. Each building type performs in similar ways, because the measures relate to the overall scale of improvement relative to the capital cost and carbon savings, e.g. insulation covers a large surface area and thus improves efficiency at relatively low costs.

Figure 17: Cost-effectiveness of measures from capital cost over annual carbon savings

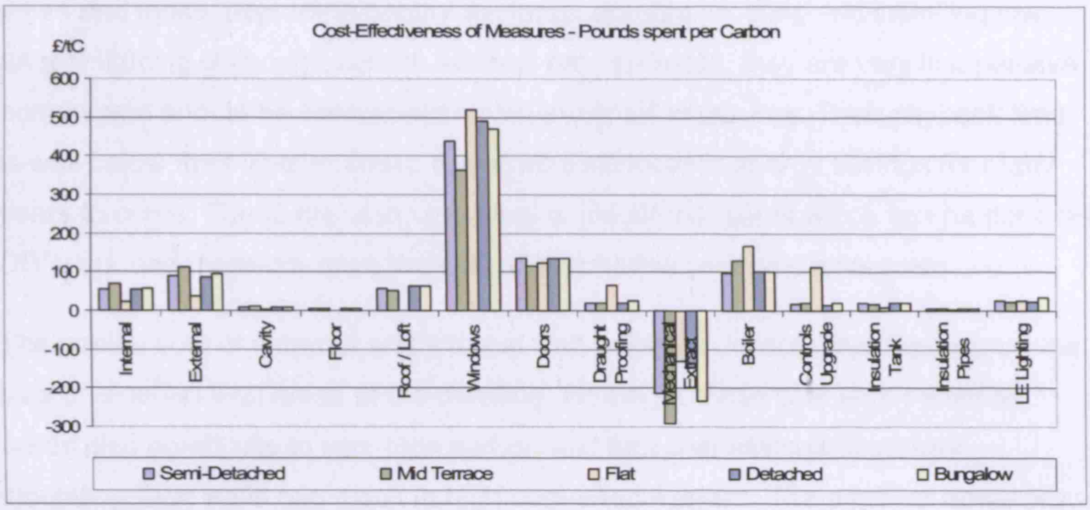
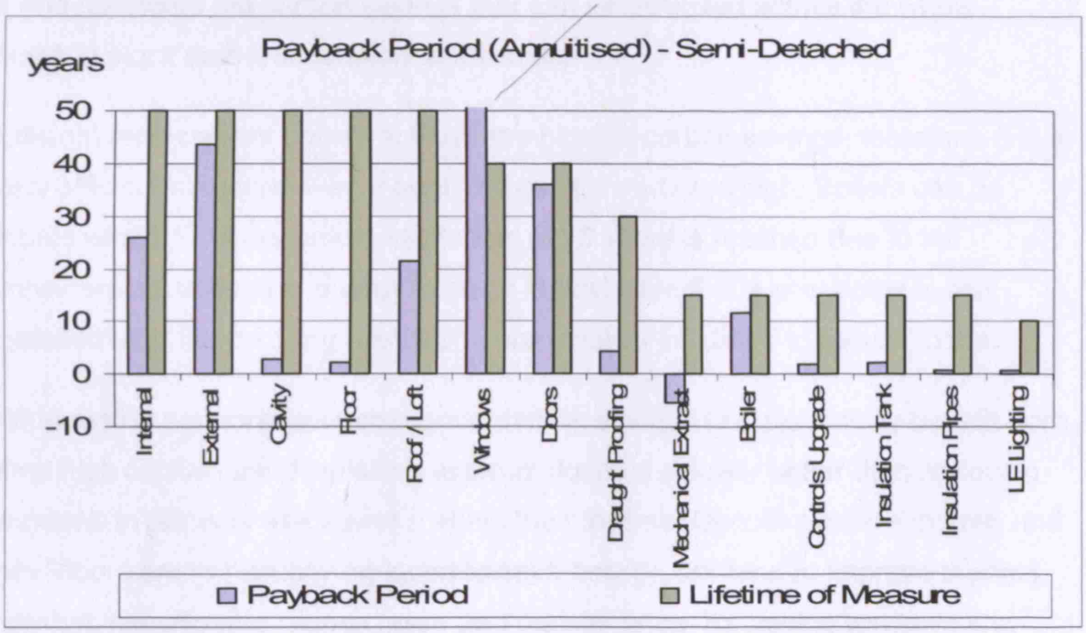


Figure 18 illustrates the cost-effectiveness from energy cost savings for annuitised payback times versus the lifetime of measures. Only the results for the semi-detached dwelling are represented because each building type shows a similar performance due to the proportionality of the energy savings to the capital cost.

Figure 18: Annuitised payback periods and lifetime – Semi-Detached



The most cost-effective measures are cavity, floor and loft insulation, insulating pipes and tanks, upgrading control systems, draught proofing and installing low energy lighting. Although carbon savings are moderate, they are very inexpensive options and should be considered as 'must-install' measures. Their payback time is well below their lifetime costs, therefore contribute to energy savings for many years to come. These are also very easy to install measures which can be done as DIY work and therefore have the potential to further reduce capital costs.

The capital cost of external and internal wall insulation is high and depends on the size of external wall areas of the dwelling. However, those with larger surface areas also contribute to very high carbon and fuel cost savings, therefore insulating their walls can result in high cost-effectiveness. The payback times are less than their lifetime, but the installation will last as long as the dwelling exists (although it is capped here at 50 years), which has an accumulative effect on cost benefits of the initial investment. The application of external or internal insulation is not always practical. For instance on flats and mid terraces external insulation requires multiple apartments to be treated simultaneously, which can be impossible if neighbouring properties prefer not to comply. There is also added limitation from planning policy that can constrain refurbishment of existing dwellings, for instance buildings in conservation areas and listed buildings. Internal insulation has the disadvantage that it reduces the habitable room sizes. Even so, if one considers the carbon savings that can be achieved across the whole building stock then it is certainly worthwhile.

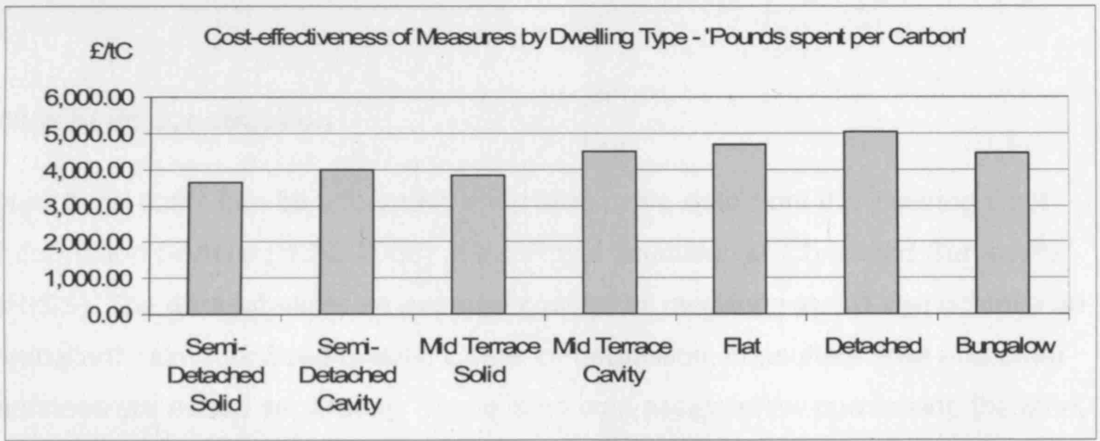
Efficient replacement boilers achieve the highest carbon savings, therefore, it is a very efficient measure even though the capital costs are high. Boilers can be repaid within 11 years before its lifetime of 15 years is reached due to the considerable savings in energy costs. It is advisable that a new boiler is only installed after the dwelling has been appropriately insulated to reduce loads.

Windows do not contribute enough to carbon savings to substantially benefit from their high capital cost. Replacing external doors is actually better than replacing windows in terms of fuel savings within their lifetime. Double glazed windows and new doors are not usually replaced to save energy, but tend to improve thermal comfort, security and reduce noise and maintenance. Replacing windows and doors can also be subject to planning restrictions, but a cost-effective solution exists in the form of secondary glazing units that can be fitted internally.

Mechanical extract ventilation is not cost-ineffective when it comes to energy efficiency, but often the improvements to thermal performance actually reduce air exchanges. This factor alone makes mechanical ventilation an important component for health reasons and building defects caused by mould and so forth.

Figure 19 compares the building types to overall cost-effectiveness and annual carbon reductions when all suitable energy-efficiency measures are applied. The results show that solid wall construction and semi-detached dwellings are the most cost-effective refurbishments when it comes to carbon savings. Detached dwellings are the least cost-effective, because the size of the building envelope requires increased refurbishment costs. Flats are also not cost-effective, because they have a small external envelope and benefit from good thermal performance. Replacing the boiler and windows requires larger investments relative to size with a comparably small return in carbon savings.

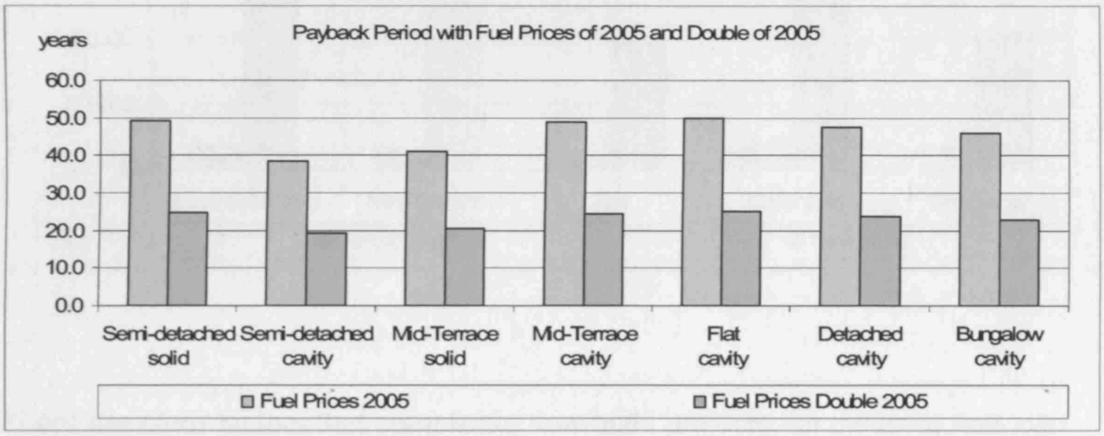
Figure 19: Capital cost versus annual carbon reductions



It is important to consider recent price increases on fossil fuels, because the payback time for refurbishing dwellings is driven by fuel savings. Any increase in annual fuel prices will undoubtedly reduce the payback time, therefore if fuel prices rise even further then payback times will be significantly reduced (see Figure 20).

Increased fuel prices expose many people to fuel poverty. Promoting and investing in energy-saving measures can help mitigate this risk, notwithstanding the added benefit of increasing energy and carbon savings.

Figure 20: Payback periods for different fuel price scenarios



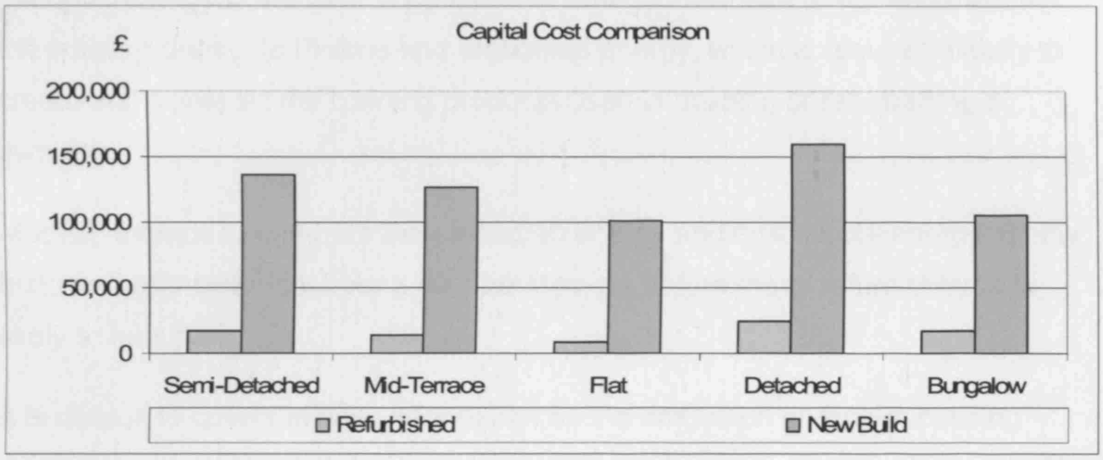
New build construction

New build costs can be accurately estimated using data from the Building Cost Information Service (BCIS 2008) of the Royal Institution of Chartered Surveyors (RICS). The data provides an average cost for all dwellings in GB that achieve an 'excellent' rating for build quality. Costs for demolition, consultant fees and other services are added separately. There is no cost assigned for purchasing the land, because this study assumes that the land owner will rebuild the dwelling.

Figure 21 summarises the total capital cost for various types of new build dwellings. The illustration recognises that the capital cost can be as much as 5 to10 times larger than the capital costs required in refurbishing existing dwellings.

It demonstrates that the investment required to rebuild outweighs the actual benefits related to energy savings.

Figure 21: Capital cost comparison – existing and refurbished



There are other factors that complicate new build projects, for instance flats can only be rebuilt if the entire housing block is demolished. Scenarios like this can increase building costs significantly, because residents have to find alternative or temporary accommodation during construction.

Paybacks, when investing on refurbishment, are quicker than new build projects, because the timescale and investment required is smaller. Model 2 has demonstrated that the cost of new build far exceeds that of refurbishment projects, regardless of dwelling type. The investment required for new build could be better spent on energy-efficient refurbishment projects. Therefore, the aim of Government should be to sponsor refurbishment projects, before turning to the more expensive and disruptive alternative of demolition and reconstruction.

An estimate shows that the total cost to upgrade the entire housing stock to 'excellent' efficiency standards, is around £200 billion, which is half the Treasury's annual budget. It is suggested that such costs could be spread over a 20-year period by diverting the Treasury's indirect subsidy of £35,000 to each new-build home (Burdett 2007).

Model 3: PRIMARY ENERGY CONSUMPTION

Our dependency on fossil fuels makes the discussion of total lifecycle energy unavoidable. A lot of research has been carried out to understand energy use in buildings but less is known about the energy used in (re)developing them.

Lifecycle energy is the total of operational energy. It is used to run and maintain the building during its lifetime and embodied energy, which is required initially to create and transport the building products used in building or refurbishing a dwelling.

Model 3 intends to compare the embodied energy and operational energy of new build and refurbishment over a 50 year lifecycle before major refurbishment is likely to take place.

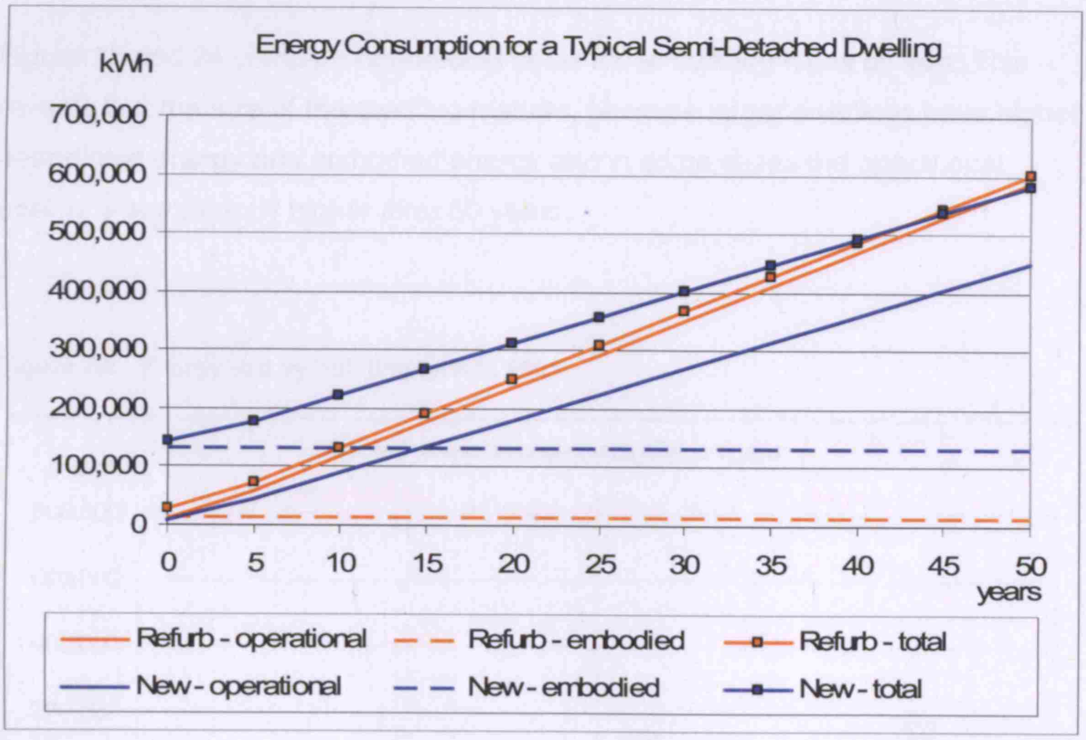
It is difficult to collect reliable information on the embodied energy of building products, e.g. energy required for transporting materials is often not included. The dissertation assesses a range of building types, but the method of construction type of materials used can vary considerably, not to mention the related impacts on embodied energy.

Model 3 uses figures from a study called 'New tricks with old bricks' by the Empty Homes Agency (EHA 2008), which compares refurbished and new build energy requirements for semi-detached dwellings. Their research found that a new build home has approximately 90 MWh (324 GJ) of embodied energy in construction materials, whilst a refurbished home only has 15 MWh (54 GJ). Using these figures as a base for the semi-detached dwellings, the dissertation interpolates these figures for other dwelling types according to size.

The analysis is dependent on the time scale that it considers. The longer the timescale the less significant is the impact of embodied energy, except for the embodied energy required for maintaining and replacing building components (e.g. windows, heating systems). The dissertation assumes that this will be the same for both new and refurbished dwellings.

The construction industry accepts that embodied energy can hardly ever be recovered during the lifetime of a building. Figure 22 demonstrates that minor works to refurbish the building will have significant reductions in embodied energy compared to new build because embodied energy is already captured within the original fabric of the building. New build dwellings have much larger amounts of embodied energy, because the existing building is demolished and the new dwelling is built from scratch. The contradiction is that a well insulated dwelling with good thermal performance using robust materials to achieve a very high build standard requires more embodied energy than an average building with inferior materials. All building types have very similar results compared to semi-detached, therefore are not illustrated here.

Figure 22: Cost for new build dwellings



When comparing operational energy, as indicated in Figure 22, new build dwellings use less energy annually due to good thermal performance and improved energy systems. The embodied energy is only accounted for at the beginning but for the purpose of this illustration lines are shown across the graph to show when they intersect with operational energy. This indicates the number of years taken to offset the embodied energy. From thereon the operational energy only becomes relevant to lifetime energy performance. As can be seen in the graph, operational energy offsets embodied energy within one to two years for refurbished dwellings, whilst new build can take approximately 15 years.

Although embodied energy is relevant, the aim should be to minimise the operational energy over the building's lifetime, because even if one were to double embodied energy, operational energy still surpasses embodied energy - it will only take a little longer. Reducing operational energy over the building's lifetime is more cost-effective than reducing embodied energy, therefore there is an incentive to apply energy-saving measures for operational energy. New build can only perform better than refurbishment when it has considerably lower operational costs.

Figure 23 and 24 compare operational costs for all building types by size. This reveals that the size of the dwelling matters, because larger dwellings have higher operational energy and embodied energy and in some cases the operational energy is significantly higher after 50 years.

Figure 23: Energy use by building type in 2001

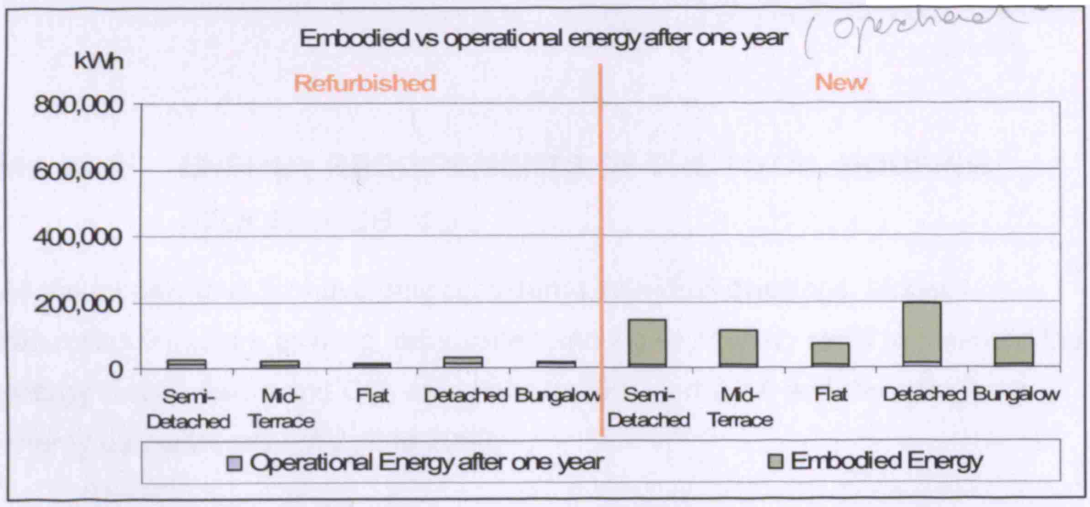
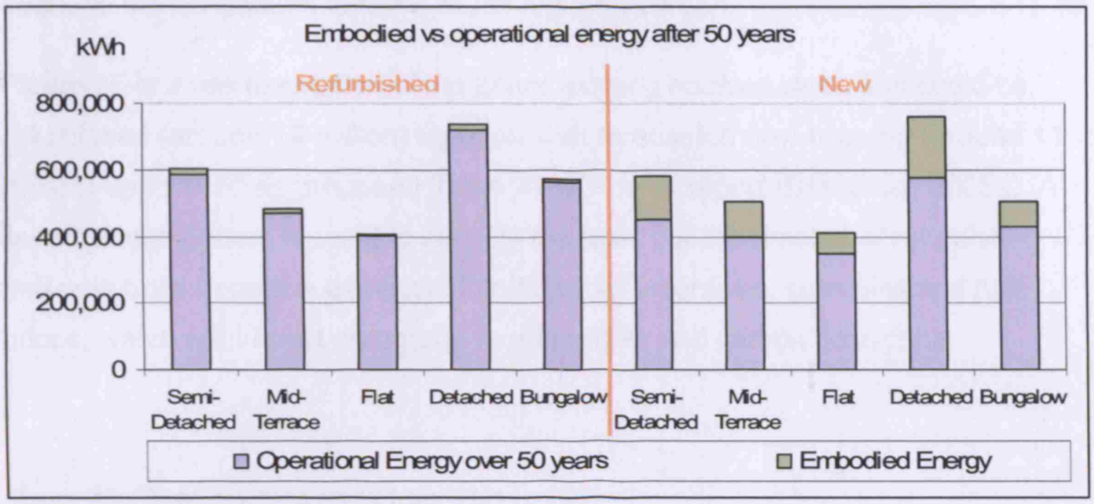


Figure 24: Energy use by building type in 2050



Model 3 calculates embodied energy based on energy use (kWh) and not on carbon emissions (tCO_2). This has a large impact on the carbon content of embodied energy, because it depends on the type of energy supplied. If operational energy could be supplied by LZC technologies, total carbon emissions would remain very low for refurbishments, thus improving refurbishments over new construction. This issue is discussed further in chapter A2.

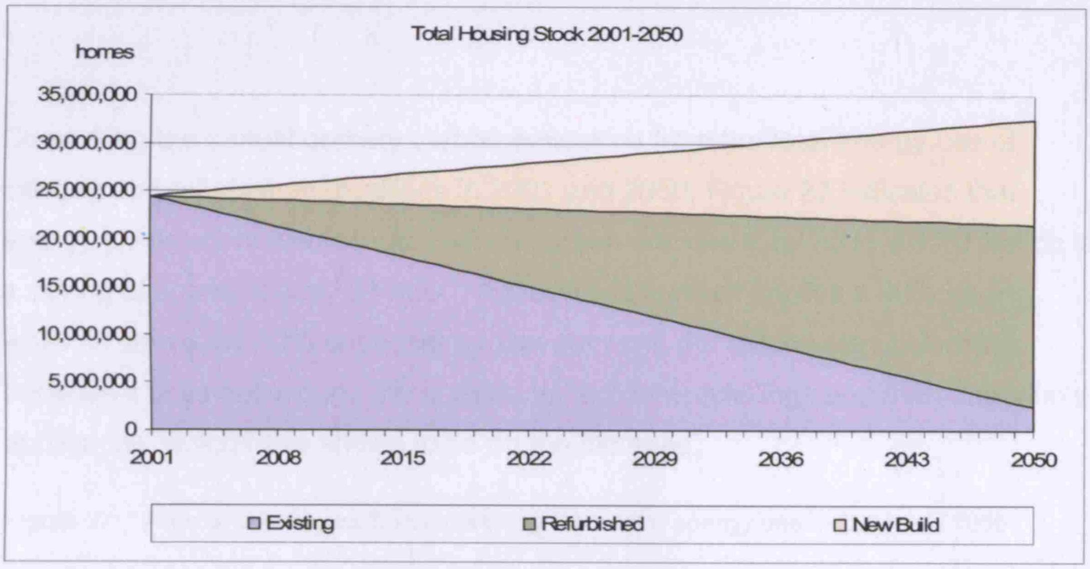
Model 4: ENERGY REQUIREMENTS OF THE TOTAL HOUSING STOCK IN GB

All the models thus far have only considered individual dwellings. Model 4 calculates the entire existing, refurbished and future housing stock to measure the energy requirements and CO_2 emissions in 2001 and 2050 and the cumulative energy demands annually up to 2050.

Model 4 uses gas to calculate the conversion factor for carbon emissions, because this is currently the primary fossil fuel supply for heating in GB. If the model used electricity as conversion factor then the results would turn out much worse, because the conversion factor is much higher than gas.

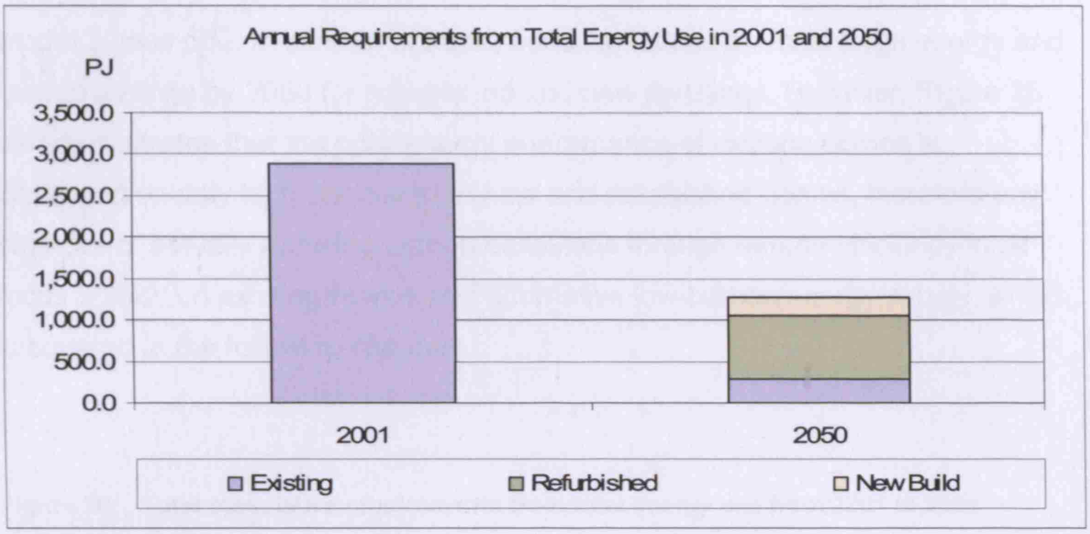
Figure 25 is a representation of the entire existing housing stock that could be refurbished (around 19 million) together with forecasted new housing (around 11 million) up to 2050 as proposed in the '40% House' report (Boardman 2005a). A linear growth pattern is used to simplify the task, but the amount of refurbished and new build homes is dependent on financial incentives, subsidies and fuel prices, which will impact on energy requirements and carbon emissions.

Figure 25: Total housing stock from 2001 to 2050



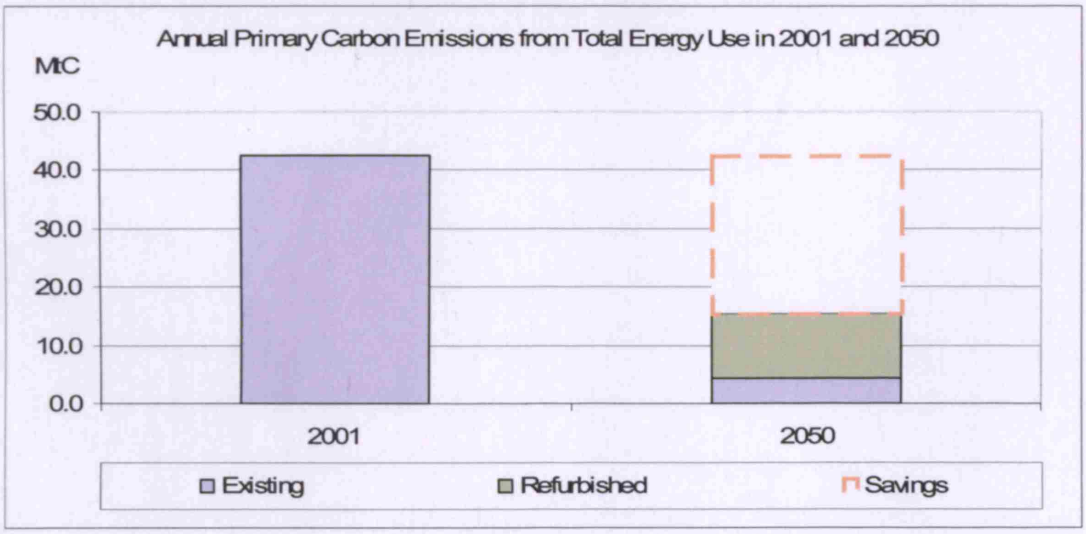
Following the projected growth of new housing and refurbishments, Figure 26 analyses the total energy requirements for the entire housing stock in 2001 and 2050. The graph demonstrates that improvement measures and new build homes reduce energy by up to a third of 2001 levels as projected in Model 2. Using data from the '40% House' report, a small proportion of existing buildings cannot be refurbished (Listed Building and/or Conservation Area), therefore other ways of reducing energy will have to be found (Boardman 2005b).

Figure 26: Annual requirements from total energy use in 2001 and 2050



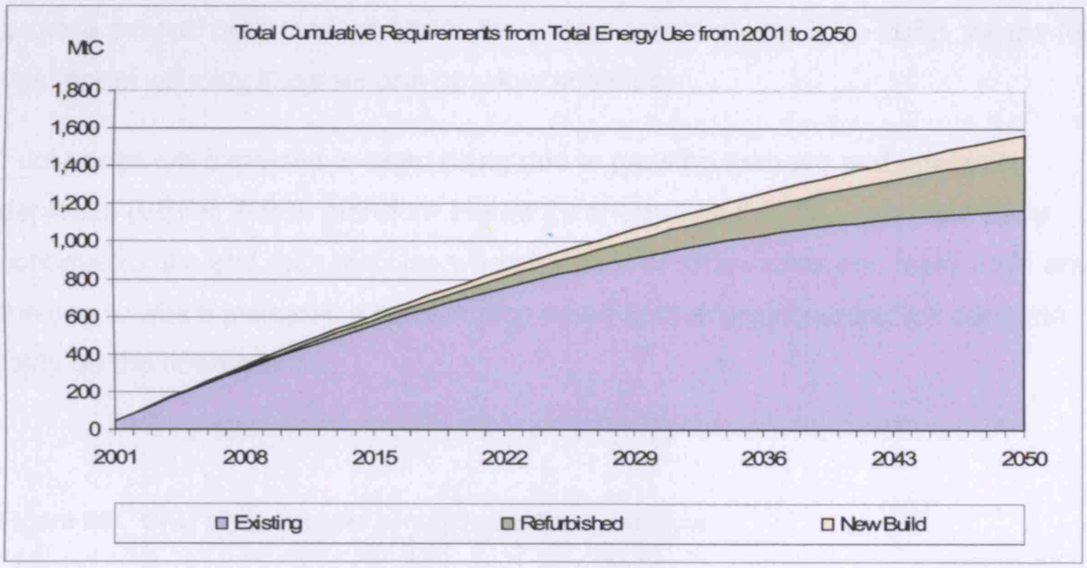
Comparing the annual primary carbon emissions from the total energy use of existing and refurbished dwellings in 2001 and 2050, Figure 27 indicates that energy-efficiency measures can reduce carbon emissions by up to a third, which is a saving of approximately 27 MtC. Although this number implies a 66% saving, which is above the 60% target set by Government, the results are misleading, because it does not include the emissions from new dwellings and from household appliances, which have shown to be on the increase.

Figure 27: Annual primary carbon emissions from total energy use in 2001 and 2050



Model 3 does offer a glimmer of hope, because it does forecast large energy and carbon savings by 2050 for refurbished and new dwellings. However, Figure 28 clearly illustrates that the poor energy performance of existing homes is disproportionately high compared to new and refurbished homes, therefore any chances of actually reducing carbon emissions through energy efficiency must focus quickly on existing homes and alternative low-carbon energy supply, which is covered in the following chapter.

Figure 28: Total cumulative requirements from total energy use from 2001 to 2050



A2

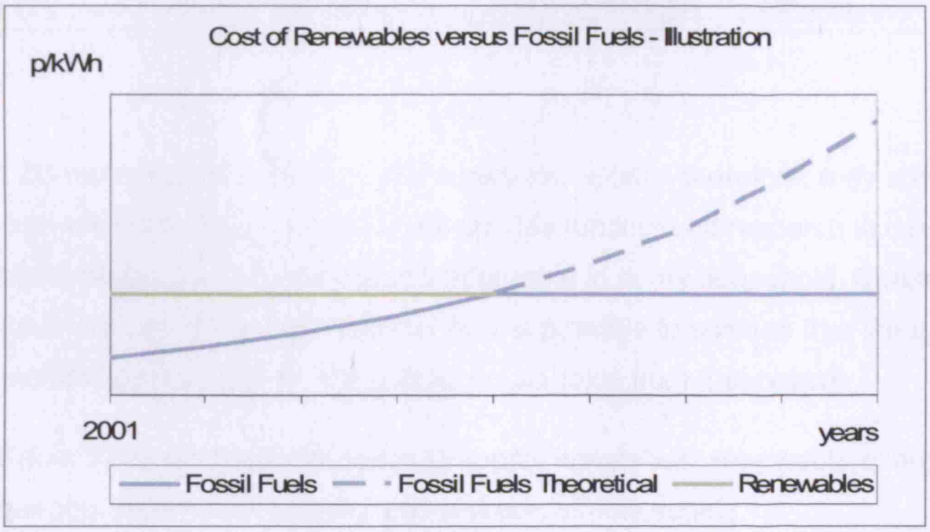
Supply side of dwellings

Model 5: CONSIDERATIONS FOR LZC TECHNOLOGIES

Model 5 looks at the supply side of fossil fuel energy provision for housing and explores the impacts of energy requirements on carbon emissions when LZC technologies are introduced. The viability of LZC technology is considered to investigate the potential to reduce carbon emissions to zero. This chapter is primarily based on theory, therefore, several assumptions are made to test the model. Although Model 4 and the 'Domestic Energy Fact File' (Shorrock 2003) provide several projected scenarios for energy requirements up to 2050, values for this model will only illustrate one possible scenario.

Fuel prices are expected to keep rising due to growing demand and upcoming depletion (BERR 2008), therefore Figure 29 anticipates that they will most likely continue to rise and then stabilise when the cost of renewables and fossil fuels are the same, which indicates a point in time when both energy sources will compete fairly on the open market.

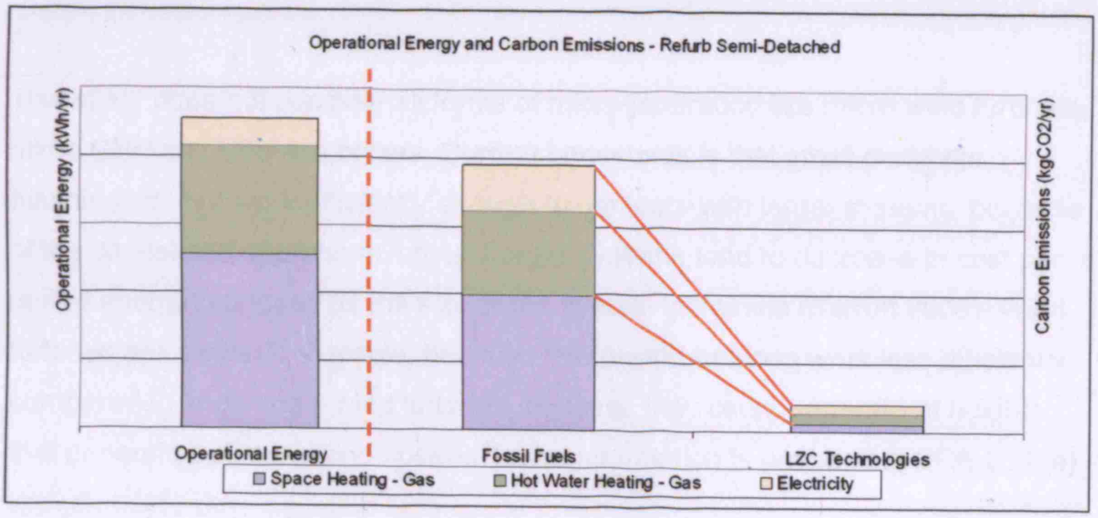
Figure 29: Cost of renewables versus fossil fuels over time



Fossil fuels will create carbon emissions with current technologies, regardless of the amount of energy efficiencies introduced in dwellings. Even with good energy-efficiency measures applied to refurbished dwellings, they still require energy supply for space and hot water heating and electricity.

Introducing LZC technologies can achieve much improved carbon savings for any remaining energy demands, as shown illustratively in Figure 30. LZC technology can contribute significantly to the reduction of heat and/or electricity demands by exploiting renewable energy forms which are theoretically inexhaustible. It is the only viable technology that has the potential to come close to zero carbon emissions.

Figure 30: Operational energy and carbon emissions illustration



LZC technologies currently have a very low uptake, therefore, they are not yet very cost-effective. A higher uptake will provide funding and research to develop the technology so that it can become affordable to every household. Considering fossil fuels are becoming more expensive, it is possible to assume that the LZC technology may relieve and protect households from fuel poverty.

Table 5 demonstrates two ways to supply homes with renewable energy for heating and/or electricity from on-site and off-site supply.

On-site supply can be produced domestically at home with microgeneration, which includes solar photo-voltaics (PV's), solar thermal hot water and heat pumps (water and air). Off-site normally consists of larger scale production of power, which is transferred to homes through a supply network. Off-site generation can employ a variety of systems, like wind turbines, hydroelectric, geothermal, wave and tidal power, combined heat and power (CHP) and district heating (DH).

Table 5: LZC technologies for heating and electricity provision

	Heating only	**Heating & Electricity**	**Electricity only**
On-site	ground/air heat pumps, solar thermal hot water	–	solar PVs
Off-site	district heating	CHP from energy using waste, biomass or gas	wind, hydro, tidal, wave

This study does not consider all forms of microgeneration like micro-wind turbines, micro CHP and biomass boilers. Current consensus is that small domestic machines do not work efficiently enough to compete with larger systems, because of the capital and operational costs. Larger systems tend to decrease in cost per unit of energy produced as the size of the system increases (Barrett 2008). Wind turbines are a classic example, because micro-wind turbines work less efficiently compared to large scale wind turbines, because they cannot operate at heights that generate optimum wind speeds (more information is provided in BRE 2008a).

The competitive edge that fossil fuels have over renewable energy supplies is reliability, but the advantage renewables have over fossil is abundance. Companies are supplying renewable energy from a variety of sources, which is not only making the technology more cost-effective, but also providing a more consistent supply. The fact that fossil fuel prices are intrinsically linked to the economy provides a big advantage for renewables, because prices tend not to fluctuate dramatically.

Figure 31 and 32 are a demonstration of an optimistic forecast of potential carbon emission reductions for the next 40 years if renewables were employed to high standards to meet required energy demands for housing (illustration only).

Figure 31: Energy use of GB housing stock until 2050 – Illustration only

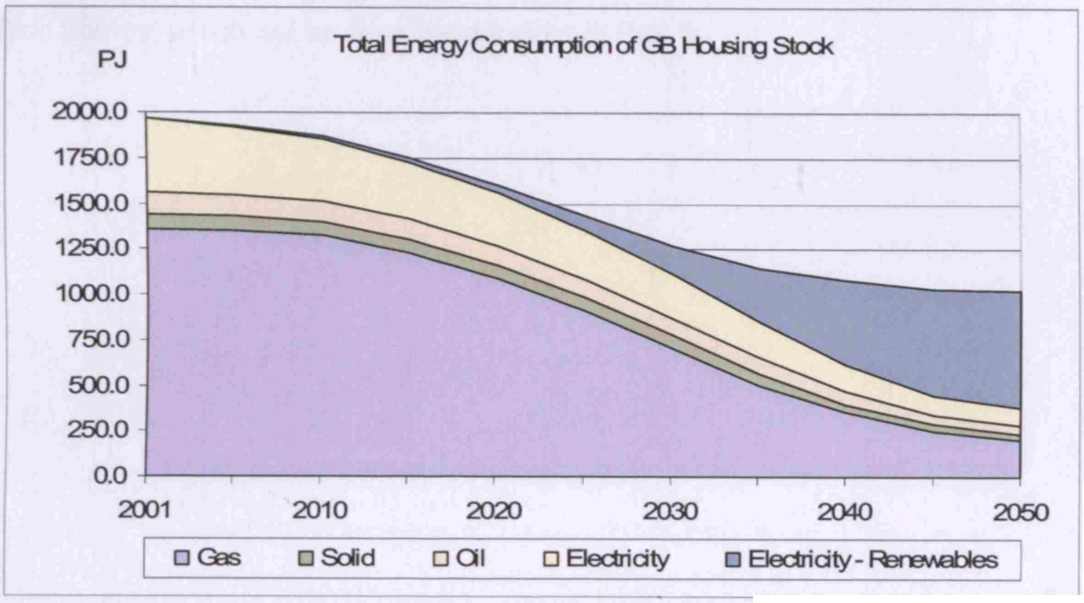
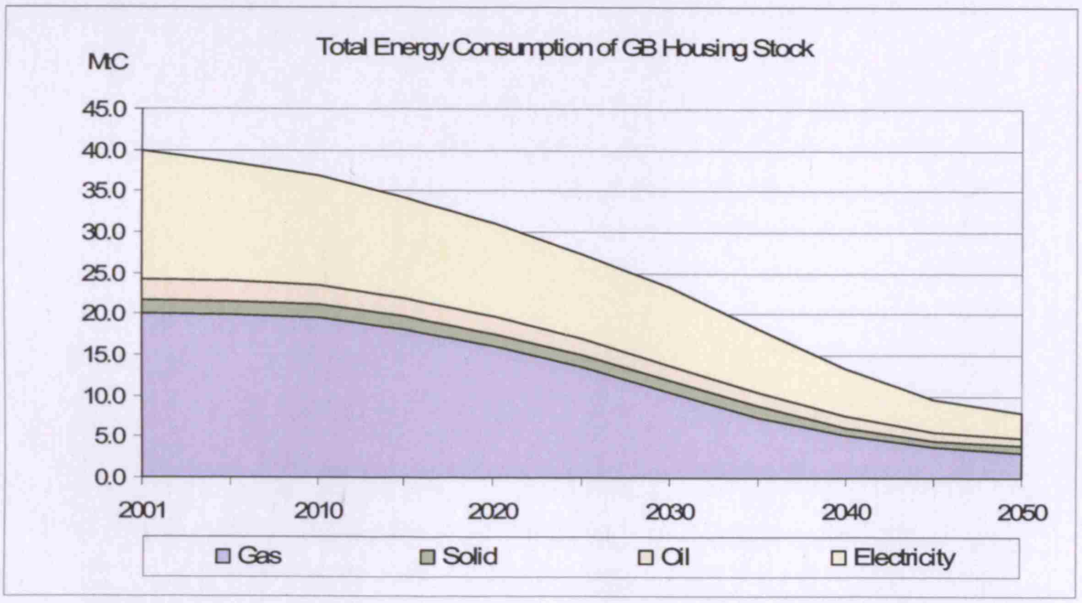


Figure 32: Carbon emissions from GB households until 2050 – Illustration only



Both graphs clearly illustrate that replacing fossil fuel with renewables for electricity supply can achieve enormous reductions in carbon emissions; therefore this measure should be seriously considered by the Government if they want to meet their expected targets. The Government must also take seriously financial incentives to assist householders to refurbish and apply renewable systems to their homes, which will be discussed further in Part B.

PART B

Non-quantified results

Following Part A, which is a quantifiable comparison between choosing to refurbish or replace existing dwellings by comparing energy costs and performance, it is important now to consider non-quantifiable issues. Part B discusses how ownership, society, heritage, fuel poverty, policy and economics can influence the decision to choose between refurbishment or rebuild.

To reduce carbon emissions from the existing housing stock the thermal efficiency and supply of energy require regulations and incentives to resolve barriers. But what could be changed to reach the targets and how could these targets be reached? This chapter also provides some suggestions for strategies which could help improve the opportunities to reach these targets.

B1

Ownership and feasibility

The likely uptake of energy-saving measures of dwellings relates strongly to ownership.

Around 80% of all housing in GB is privately owned. Nearly three quarters belong to the occupier with the remainder being privately rented. The remaining 20% are split into 16% ownership by local authorities (LA) and 5% registered social landlords (RSL) (Shorrock 2003).

On average, the social housing stock is more energy-efficient by energy per floor area with a higher improvement rate than privately owned dwellings (Killip 2008). The private sector is estimated to be a decade behind the social housing regarding energy efficiency (House of Commons 2008).This is firstly due to dwelling types, because social housing is primarily more modern and smaller in size; for example, housing associations will tend to own an entire block of flats rather than detached houses. Secondly, a large volume of refurbishments is managed by RSLs and

LA's who have over the years learned much through repeated experience and have established good relationships with contractors. Hence, they tend to be a lot better at commissioning low-carbon refurbishment projects. Social housing is usually constructed on larger estates, therefore benefit from economies of scale. For example, price reductions can be offered for bulk orders and it is much cheaper to insulate a row of terraces than it is to insulate a detached house. Thirdly, social housing has stricter governmental requirements to fulfil. This sector offers a good opportunity to provide benchmarks for low-energy frameworks, which are then tested over time to establish minimum standards.

Owner occupiers apply more energy-saving measures than owners of rented homes. This is because they are less likely to move, thus, see a return on their investment through cheaper utility bills, which are paid by themselves (Shorrock 2003).

The worst performing housing is detached private homes, especially with high property value, which tend to be occupied by households on higher incomes (CLG 2006b). Often wealthier households tend not to be directly affected by increased energy costs (relative to their income), therefore do not share the same concerns as poorer households.

The viability of refurbishment or new construction is also strongly linked to building type. For example, a flat cannot be demolished and rebuilt without the whole block following suit. In addition, flat refurbishments have limitations of range of measures that can be applied. For example, it is not possible to insulate a flat externally if the surrounding flats are not partnering in. Yet, there is a large potential for owners of flats or terraces to cooperate in joint energy-saving measures as a community. This could involve cost reductions on mass orders for energy-efficient windows and insulation or employing an energy savings company (Esco) to provide energy reductions at a larger scale; for instance, providing district heating from a CHP plant. However, this requires strong leadership, cooperation and coordination. These options are difficult to achieve for owners of detached or semi-detached properties.

B2

Societal parameters

The energy use in the UK is greatly affected by social parameters such as 'the size of the population, the number of households and the composition of the housing stock in terms of age [...] and regional distribution' (Shorrock 2003, p.27).

The UK population is projected to increase from 59,6 million in 2003 to approximately 66,8 million in 2051. Therefore, according to the 'Home Truths' report (Boardman 2007), there could be 23% more households in 2050 and hence more energy requirements.

Combined with this trend is the forecast that the number of occupants per household will decrease (Boardman 2005b). Even if the trend did move towards larger households, demand for additional housing would still increase and consequently cause higher consumption per capita (Shorrock 2003).

Occupational behaviour has also changed when it comes to comfort of internal room temperatures which has risen by 6° C since the 1970s; and is likely to rise further (Lowe 2008). This in itself will require additional energy provision.

Considering all these factors together, there is no doubt that an assessment is needed to fathom whether refurbished building can be designed and adopted with enough flexibility to deliver the required demands or whether more specialized new construction is needed to satisfy energy needs.

Furthermore, land availability and house prices will vary with time and have a strong influence on the spending capacity of buyers, owners or developers. The current slowdown in the market is evident that new developments have diminished, because banks are not prepared to lend money and people are cautious not to overstretch themselves financially. Under current economic situations, it is better to refurbish, because it is a more lucrative option.

B3

Heritage and character of place

National policy prevents the loss of unique heritage, therefore replacing Listed Buildings is certainly not an option. There are 370,000 Listed Buildings in GB and a further million unlisted buildings in Conservation Areas (House of Commons 2008). These buildings are excluded from having to comply with Part L of the Building Regulations for energy-efficiency requirements. However, refurbishments and/or extensions can be designed with innovative approaches to improve energy saving standards and outdated internal layouts without destroying the external fabric or identity of the building.

In general, existing buildings contribute to the local character of a place with its historic, architectural and cultural features, whereas new developments often lack reference to the surroundings.

New build properties can have a strong impact on the social network of an existing community. It should also be considered that often house prices are much higher for newly constructed dwellings which can cause disruption to the social balance of the local community.

Housing density can also have a major part to play when it comes to energy efficiency. Councils tend to cap new developments to very low density levels.

B4

Fuel poverty

There are currently around 4.5 million households in the UK that live in fuel poverty (Times 2008). Fuel poor and vulnerable households (elderly, disabled and low-income) cannot afford to pay their fuel bills and maintain a comfortable lifestyle, let alone afford to build a new and more energy-efficient home.

Fuel poverty is defined as '*when a household has to spend 10 per cent or more of its income on energy to maintain a warm home*' (Defra 2007, p.32). It is often linked to low-incomes, unaffordable fuel costs and inadequate energy efficiency of homes.

The Government has given a legal commitment to abolish fuel poverty from vulnerable households by 2010 and in all English households by 2016. Numbers fell from 1996 to 2004 by 1.2 million. Since 2003 there has been a significant rise in fuel prices, which is again increasing the number living in fuel poverty and it is likely to grow further in 2008/9. This puts the Government in a difficult position to meet its obligation by 2010 (House of Commons 2008).

One way to prevent fuel poverty is to improve the energy performance of existing homes. As shown earlier, this measure is the most cost-effective way of contributing toward a reduction in energy bills and protecting current and future occupiers from rising fuel prices. LZC technologies should also be subsidised for those living with fuel poverty, because it will dramatically reduce dependency on fossil fuel costs.

Grant funding is available from schemes such as Warm Front, Decent Homes, the Low Carbon Building Programme (LCBP) and the Carbon Emissions Reduction Target (CERT) which will be discussed in the following chapter. However, the Government was criticised, because funding was not reaching far and fast enough to tackle fuel poverty (Boardman 2007).

B5

Policies, incentives and implementation opportunities

In order achieve the Government's targets for reducing carbon emissions, a strong support system is required to apply energy-efficiency measures to existing and new build dwellings. Government needs to incentivise householders to invest in energy reduction measures. It also needs to encourage developers and industry to develop and innovate a variety of affordable energy saving products.

The following sections describe briefly the current and possible mechanisms the Government have put in place to deliver change. The main categories are divided into:

- Legislation
- Regulations
- Voluntary agreements
- Grants and fiscal incentives
- Information and awareness rising

Legislation

Housing policy is guided by national policy and legislated by regional and local frameworks and action plans.

National legislation places duty on regional authorities and local councils to implement national requirements to delivering Government policy, which set minimum standards for various issues including housing, energy and, carbon reductions, etc. Regional authorities and councils develop area action plans and planning frameworks to control the type and quality of development in an area, especially for new housing. Every borough in the UK has established its own criteria for energy efficiency and carbon reductions for housing, which often set measures higher than national guidance.

The local council enforce planning policy to ensure Area Action Plans are delivered, but often it is difficult to enforce, because it is dependant on the developers or householders ability to afford the measures. Each region has varying degrees of success in achieving Government guidance on reducing carbon. This is even harder to legislate and control for refurbishment, especially for individual households.

Regulations

For the conservation of fuel and power, the Government sets out mandatory energy-efficiency standards in Part L of the Building Regulations. This stipulates that all new housing must be 40% more energy efficient than homes built in 2002 (Defra 2007). Future publications will be progressively tightened so that all new homes built in 2016 must achieve zero carbon standards by improving energy performance and installing LZC technologies.

The Building Regulations have also set mandates on existing dwellings to promote consequential improvements to individual building components (e.g. boilers, windows) when building work is being carried out. Most refurbishments do not require planning approval, unless the works alter the external fabric or extend beyond the existing building envelope. This often results in refurbishment work not having to comply with energy-efficiency measures set by the Council. However, Building Regulations do demand that substantial transformations to thermal building elements must be upgraded, but it does not far enough, because it excludes improvement works to the energy performance of the entire dwelling (Killip 2008). Therefore, the potential for improvement measures only reaches about 2-3% of the full stock and is by far not exhausted.

Building Regulations should broaden energy saving measures, especially in major refurbishments where the overall performance of the dwelling is improved. Homes should be enhanced to a much higher energy saving level as part of building control on a national level and assure impact on carbon savings on a much larger scale (House of Commons 2008). This is politically difficult because it would put a financial burden on poorer households which may then decide not to refurbish at all, which could be worse. Governmental subsidies need to be made available to cover the extra costs for poorer households.

Building Regulations offer an opportunity to correct market shortcomings and generate responsible actions.

Voluntary agreements

The CSH is a six-star rating based on the energy efficiency of new sustainable homes, but only in England. Scotland has energy-efficiency measures in their building standards and Wales and Northern Ireland have to meet 'excellent' ratings of Ecohomes, the predecessor of the CSH (Defra 2007).

The CSH not only includes energy-efficiency targets, but also sets targets for water, materials, waste and ecology. Energy and water credits cannot be traded and hence higher code levels will show an improved performance in these categories.

The CSH has seen a large uptake despite being a voluntary commitment for private housing. Government driven developments are obliged to achieve at least a code level three. Besides improving energy savings CSH also promotes the use of LZC technologies by rating it higher in the accreditation assessment. The Code encourages house builders and developers to go beyond minimum compliance, which has put more emphasis on setting higher standards on revised Building Regulations (Defra 2007). There is currently no equivalent system available for refurbishments, which is now under review by Government.

The Code for Sustainable Homes should equally be expanded so that also existing dwellings work towards set standards for carbon, water and waste reductions. Publicly funded refurbishments should be based on high code levels to set benchmarks for best practice. The code levels could act as a comparison tool like a SAP rating.

Local frameworks manage how developments take place in councils. Prepared by local authorities, framework documents set standards for planning applications. For instance some councils may put recommendations together for cutting carbon by setting conditions for approval based on the CSH or their own criteria.

The implementation requires an instrument of adequate control for compliance to avoid loopholes and negligence.

Grants and fiscal incentives

At present, there are four major subsidy programmes in place, which mainly exist for home improvements that increase energy efficiency.

Carbon Emissions Reduction Target (CERT)

This programme replaced the Energy Efficiency Commitment (EEC) in 2008. The Government have enforced obligations on energy suppliers to offer energy-efficiency measures to householders, especially in 'able-to-pay' and priority groups. The energy supplier has to invest in appliances, heating systems, lighting and insulation measures and from 2008 must also include microgeneration. Unsurprisingly, in a competitive market, suppliers focus on inexpensive methods to comply with their obligations, which is called concentrating on 'low-hanging-fruit' (House of Commons 2008). Much of the current improvement works has been funded this way and the programme proved very successful since its inception in 2002 (CLG 2006b). It is important to promote future provisions that will shift from inexpensive familiar measures towards new and more expensive and efficient technologies.

Currently, energy savings are estimated and not measured. In 2011, when this programme expires, it will be replaced by the Supplier Obligation, a cap-and-trade system which will measure consumption and therefore will improve its effectiveness even further (Boardman 2007).

Warm Front

Targeted on low-income owner occupiers or tenants, this grant programme funded by the Government in 2000, helps the fuel-poor and vulnerable groups to overcome fuel poverty by improving homes through energy-efficient measures, including insulation and heating systems. The programme has been criticised, because there is insufficient amounts of grant available (House of Commons 2008).

Decent Homes

Aiming at social rented households, the Decent Homes programme was established in 2001. Local authorities often work closely with CERT suppliers to improve social housing to a minimum standard of thermal insulation by 2010. Because this programme is not specifically aiming at energy efficiency, the standard seems insufficient and consequently it has not proven very successful in delivering carbon savings (CLG 2006b).

Low Carbon Building Programme (LCBP)

Under the Government's challenge 'power from the people', new and existing homes that are fairly energy efficient are eligible for a grant towards the capital cost of installing microgeneration systems as an alternative or supplementary energy generation source to all households in the UK. Grants were made available from 2006, but uptake lags far behind other countries such as Germany and Spain (Boardman 2007). Furthermore, the programme is very complex to manage and has run out of money twice within the first phase (Richards 2007).

Separate to the four existing programmes above it would be beneficial to implement a 'renewable obligation'.

Renewables obligation

The Government should introduce renewables obligation targets, which would enforce households to integrate a part of their energy provision from renewable sources. In Baden-Württemberg (Germany) a regulation has been established that kicks in when mechanical equipment is replaced, which states that at least 20% has to be provided from on-site or off-site LZC technologies. Emphasis needs to be placed on feasible LZC technologies as explained in Chapter A2.

In addition to these grants, there are also a number of tax incentives available to promote carbon savings in the housing stock.

Stamp duty rebate

The rebate compensates high energy-efficiency improvements to new and refurbished homes at point of sale.

New homes performing to zero-carbon standard are excluded from stamp duty if the building costs less than £500,000 and receive a rebate of £15,000 on stamp duty if the building costs more.

For existing home owners it is difficult to attain rebates because the tax has to be paid before refurbishment works is started. Home owners often have limited finances, therefore it tends to attract wealthy homeowners who are able to afford the upfront capital costs. This will only work if the tax can be paid after the work has been completed, until then stamp duty will not be an incentive for the average homeowner refurbishing a property (Killip 2008).

In addition, stamp duty is only eligible at the point of construction or sale of the home, therefore it can only apply to half of all existing properties within a decade (House of Commons 2008).

Value Added Tax (VAT)

The Government is encouraging existing home owners to take up energy-saving measures by reducing VAT rates to 5% on energy-saving materials and equipment. However, the reduced rate only applies to professionally installed systems. It does not include DIY applications, which would certainly attract many more home owners, who currently pay 17.5% VAT (Defra 2007).

In contrast, new buildings pay no VAT on energy saving measures, therefore the incentives are disproportionate. It sends out the wrong message, because it rewards projects that demolish and rebuild by making it more profitable to rebuild than to refurbish to a higher environmental standard.

By European law, VAT can only be legally levied to rates of either 5% or 17.5%. The Government is committed to pressing for reduced rates on energy-efficient products to equalise VAT rates for new build and refurbishment projects (Defra 2007).

Landlord's Energy Saving Allowance (LESA)

As discussed in Chapter B1, private landlords are least likely to undertake energy-saving measures. To offer incentives to private landlords to improve properties they let, the LESA scheme was introduced in 2004. The scheme provides upfront relief for capital expenditure for investments on energy-saving measures such as insulation and draught proofing (Defra 2007).

In the following, further financial incentives are suggested for implementation that could achieve further carbon savings in the housing stock.

National council tax rebate

Several academics and politicians have suggested that a national council tax rebate scheme could be employed to encourage people to upgrade their homes to reach a higher performance band by rewarding these actions with a cut in council tax. Care needs to be taken that the rebate will not only be available to the 'able-to-pay' but to ensure equity of installation and return. Unlike stamp duty rebates, the advantage is that council tax rebates would be available every year as council tax has to be paid annually. To sustain financing from councils, a support mechanism is required which may be funded centrally. The Government are considering this option, but there are no signs that it will be implemented.

Low interest loan schemes

Low interest loan schemes, which are available in other countries, like Germany that provides assistance to homes built before 1984, would entice home owners to undertake energy-efficiency improvements to older dwellings. People are offered a loan fixed at a low interest rate (subsidised by government) and when the work is successfully completed the Government will repay 10% of the loan. Refurbishment would be considered successful if the dwellings total CO_2 could be reduced 40 $kg/m^2/yr$. The scheme has proven very successful in Germany, which is purely voluntary (Moore 2008).

Feed-in tariffs

Feed-in tariffs should be implemented by Government to guarantee an established fixed rate as a payback for electricity generation which is sold to the national grid from home owners installing microgeneration systems like PV's. Emphasis should be placed on rewarding households for energy saving systems instead of promoting high consumption. This measure has been successfully applied in Germany and proved effective to boost the economy and encourage people to invest in larger systems to maximise the rewards offered (Killip 2008). The LCBP programme is currently only subsidising the purchase of LZC equipment and has therefore not seen a huge engagement.

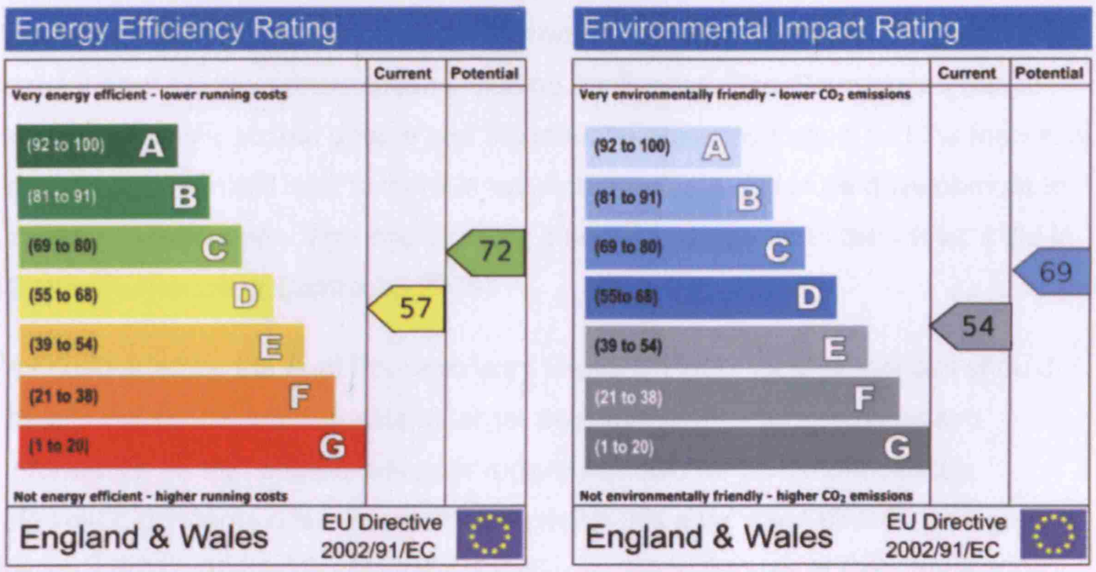
Information and awareness raising

Energy Performance Certificate (EPC)

The EPC was introduced in 2007 as part of the Home Information Pack (HIP), which is a requirement under the European Energy Performance of Buildings Directive. Full implementation is currently planned for 2009.

During the construction, sale or rent of buildings, the EPC will inform the potential owner or tenant about the current energy consumption and emissions of the property and provide information on its cost-effective potential for improvements with an energy rating on an A-G scale (A being best performance).

Figure 33: EPC Rating (Boardman 2007, p.43)



The EPC will only apply to a fraction of all housing stock, unless all homes are required to prove energy-efficiency ratings.

Although the EPC on its own will not stimulate the changes required it will set into motion the action needed to raise awareness and eventually change consumer's attitude to sustainable design and construction. To have a real impact, policy measures will have to be introduced and enforced so that the market is stimulated to provide the necessary services and skills to implement the changes required (Killip 2008).

The Government has announced a 'Green Homes Service' delivered by the EST to improve the worst performing homes (House of Commons 2008). Government has suggested that homes in band F or G cannot be resold until energy-efficiency improvements have been applied (Moore 2008).

It is essential that all available policies are recognised. Policies currently are not focusing on the household's behaviour or encourage them to change. Through communication and feedback, people have to be made aware of the urgency to act and be presented with available options. For example, successful refurbishments could be more widely promoted to raise awareness and standards.

In addition, standards and agreements from the industry are needed to reduce the impact from energy consumption including appliances. The Government has to lead by example so that people and the industry are encouraged and the market is stimulated which will lead to more innovation, research and skills development to improve technologies. This could create a successful market in the UK as it did in Germany (House of Commons 2008).

As suggested by the Fuel Poor Advisory Group (FPAG), local authorities should be allowed to use internal data to target available grants, programmes and information so that eligible fuel poor recipients could be contacted directly. However, concerns over data protection make this a very sensitive issue legally which would certainly require careful implementation (House of Commons 2008).

Throughout this chapter, it is evident that Government policy is not equally balanced, in as much as new build is enforced by mandatory regulations and encouraged by tax incentives to achieve high environmental standards. To achieve carbon reductions for the majority of existing housing stock in the UK, more competitive incentives and alternative policy needs to be introduced.

As calculated in Part A, costs and payback times can be reduced for refurbishment, but suitable policy does not exist to offer enough incentive to counteract the perception that it is better to replace them with new homes.

Grants available for energy-efficient refurbishments is largely dependent on initiatives by home owners, therefore without appropriate information and mobilisation from Government the uptake of energy-saving measures will not be considered or afforded by millions of home owners. Government assistance mainly focuses on conventional short payback measures, which is promoted in current policy, therefore it is highly unlikely that the 2050 target for reducing carbon emission by 80% will be achieved (Moore 2008).

As emphasised in Chapter A2, a shift toward LZC technologies should be promoted more vigorously. If refurbishment is to be considered above new build then incentives need to be put in place to incentivise home owners to invest in the technology, which go beyond LCBP incentives described above.

This also requires a shift away from voluntary measures toward mandatory low-carbon measures that promote refurbishment.

The list of incentives above summarise the potential to unlock a faster uptake for energy reduction schemes. As seen from the housing stock models, it is crucial that existing houses get refurbished quickly so that immediate reductions can achieve larger benefits over a longer period of time. The longer we wait the more difficult it will be to achieve required reductions by 2050.

B6

British Construction Industry, Buildability and Economy

The British construction industry has recently engaged with energy-saving measures, but it happened much later than in some other European countries like Denmark and Germany. As a result, the industry is catching up on training and investment, but Government policy and support is required to speed up the process, especially if Government want to reach its own targets for carbon reductions.

The construction industry has to adopt and develop new services quickly. It also needs to provide energy-saving construction methods throughout the production and procurement chain, especially for refurbishment projects.

There is generally insufficient experience amongst architects and builders regarding sustainable design. Most build to limits in Building Regulations rather than challenging higher standards because it is cheaper and less time consuming. Therefore, time and financial considerations take priority over sustainable design. Although the situation has improved, there is still a lot of scope to make sustainable construction common practice. Part A is based on 'best practice' standards for new homes, therefore to achieve the required carbon reductions, the entire construction industry needs to perform to at least that standard.

Refurbishment improves dwellings that are insufficient, therefore a 'patch work' of measures will improve building defects compared to buildings started from scratch, which inevitably suffer teething problems. It is without saying that the measures used in the calculations are based on traditional construction methods, therefore carry lower risk of failure than modern methods of construction. To make the refurbishment market successful it is crucial that improvement measures are simple and fast to implement. General repair and maintenance work offer a great opportunity to integrate low-carbon improvements.

According to recent research 'How Low' by Moore, energy-saving measures could generate £1 worth of economic potential for the UK economy for every £3-4 spent on refurbishment (Moore 2008). This is a considerable potential for the building industry to create jobs and stimulate new business and also assist households gripped by fuel poverty.

Conclusion

As discussed Chapter A1, it is evident that current energy-efficiency standards are poor for the majority of existing dwellings in GB. In order for Government to reach its carbon reduction targets, millions of existing dwellings need to improve energy-efficiency standards urgently through refurbishment or rebuild.

Part A demonstrates that refurbished dwellings of all types can operate close to energy-efficiency levels required at much lower capital cost and energy input during construction (embodied energy); therefore refurbishment is preferred before turning to the more expensive and disruptive alternative of demolition and reconstruction.

Refurbishing of all existing homes cannot happen over night, but technologies are available and are continually improving with experience and knowledge. Energy performance will inevitably improve, but it is dependant on uptake. It is crucial that higher numbers of existing houses are refurbished annually, so that larger reductions can be achieved in a shorter period of time.

If the construction industry can target the worst performing buildings, then proportionally larger increases in energy savings will be achieved. Chapter A1 demonstrates that this method will reduce carbon emissions most effectively.

Fuel scarcity and climate change emphasise the need to reduce our dependency on fossil fuels. If one considers that the construction industry is limited financially and logistically to the number of new builds that can be achieved annually, the majority of houses will still be around by 2050. Therefore, refurbishment with energy-efficient measures and retrofitting all buildings with LZC technologies will be necessary.

As demonstrated in Chapter A2, in order to maximise the cost benefits of carbon reductions, it is important to first apply energy efficiency measures to lower energy demand and then switch attention to increasing supply from renewables.

It is essential that LZC technologies are affordable to all homeowners so that the uptake from fossil fuels to renewable energy sources can happen quickly. This is evident from the results in Chapter A2, which demonstrates affordable LZC technologies are key to decarbonising energy use in buildings, whether refurbished or new build.

Part B recognises that the uptake of refurbishment and LZC technologies can only be successfully implemented if the right regulations, policies and funding streams are in place. Chapter B5 acknowledges that regulations and financial incentives are necessary to establish enough momentum to achieve low-carbon standards for all income groups. As demonstrated in Part B, more work is required to promote and secure the transformation of the existing housing stock, therefore Government intervention is required to provide appropriate policies and incentives through regulations, grants, tax initiatives and public-wide information and awareness programmes. In addition, it requires more competitive incentives as well as policy that can reach every type of home owner or tenant.

Chapters B1 to B4 demonstrate that some issues such as heritage or societal parameters can limit the feasibility for refurbishments or new construction and must be considered in context to energy performance with sensitivity to character on an individual basis. However, these issues should not hold off the large majority from uptake.

Chapter B6 highlights the economic opportunities that come along with refurbishments and sustainable construction with the potential to provide new skill and development.

Refurbishment in combination with LZC technologies will benefit a larger sector of society through improved comfort and reduced running costs, which will ultimately help alleviate fuel poverty and energy waste.

The dissertation demonstrates that refurbishing existing homes is more cost-effective and energy-efficient than rebuild, therefore theoretically is more likely to achieve the Government's targets of reducing carbon emissions.

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Appendix 1: SAP calculation results for existing dwelling types

Existing Housing Stock in Great Britain, 2001									
Dwelling Type		Units	Semi-Detached		Mid Terrace		Flat	Detached	Bungalow
Total Number:									
% of Housing Stock	Total = 24,422,000	%	28.4%		27.7%		18.9%	16.2%	8.4%
Number of Dwellings	Total = 24,422,000	(1,000s)	6,936.00		6,766.00		4,639.00	3,956.00	2,051.00
Building Details:									
Age			before 1930	after 1930	before 1930	after 1930	1960	before 1930	1945
Location			Sheffield		Sheffield		Sheffield	Sheffield	Sheffield
Shelter - Exposure			2		2		4	2	2
Household Occupants			3		2-3		2	3	2
Total Area		m^2	89.00		79.00		61.00	104.00	67.00
Plan Aspect Ratio 1.4	Width	m	5.64		5.31		6.60	6.09	6.92
	Depth	m	7.89		7.44		9.24	8.53	9.69
Building Perimeter		m	19.50		10.00		13.20	29.20	33.20
Number of Storeys			2		2		1	2	1
Storey Height	Ground Floor	m	2.40		2.40		2.40	2.40	2.40
	First Floor	m	2.60		2.60		0	2.60	0
Ventilation:									
Draught Lobby			no		no		yes	no	no
Draught Proofing		%	0%	50%	0%	50%	50%	50%	50%
Pressure Test @ 50Pa			no		no		no	no	no
Air Change Rate		ach	5.00		5.00		5.00	5.00	5.00
Thermal Bridging		W/m^2K	0.15		0.15		0.15	0.15	0.15
Ventilation System			natural		natural		natural	natural	natural
Vents	Chimneys		1		1		0	1	1
	Open Flues		1		1		0	1	1
	Fans / Vents		0		0		0	0	0
Effective Air Change Rate	SAP (25)	ach^{-1}	0.88		0.90		0.64	0.85	0.96
Heat Losses:									
Ground Floor	Area	m^2	44.50		39.50		0.00	52.00	67.00
	Living Area	m^2	26.70		23.70		18.3	26.00	33.50
	U-value	W/m^2K	0.70		0.70		0 / 0.70	0.70	0.70
Walls	Area (incl. openings)	m^2	97.50		50.00		31.68	146.00	79.68
	Wall Type		solid	cavity	solid	cavity	cavity	cavity	cavity
	U-value	W/m^2K	2.10	1.50	2.10	1.50	1.50	1.50	1.50
Roofs	Area	m^2	44.50		39.50		0	52.00	67.00
	Pitch Angle		35°		35°		0	35°	35°
	Loft Insul. Thickness	mm	25	100	25	100	0	100	100
	U-value	W/m^2K	1.00	0.40	1.00	0.40	0 / 0.40	0.40	0.40
Windows	Area	m^2	17.00		16.00		7.00	19.00	13.80
	Glazing		single	1/2 double, 6mm	single	1/2 double, 6mm	1/2 double, 6mm	1/2 double, 6mm	1/2 double, 6mm
	U-value	W/m^2K	4.80	3.10	4.80	3.10	3.10	3.10	3.10
External Doors	Area	m^2	3.70		3.70		1.85	3.70	3.70
	U-value	W/m^2K	3.00		3.00		3.00	3.00	3.00
Heat Loss Coefficient	SAP (37)	W/K	408.75	314.40	284.39	222.21	132.30	415.87	298.90
Heat Loss Parameter (HLP)	SAP (38)	W/m^2K	4.59	3.53	3.60	2.81	2.17	4.00	4.46
Gains:									
Lighting	Number of LE Fittings		0 of 8		0 of 7		0 of 5	0 of 10	0 of 7
Internal Gains	SAP (55)	W	785.55		731.54		579.22	865.20	665.77
Solar Gains	SAP (65)	W	367.31	328.42	304.80	272.53	185.81	365.30	259.61
Useful Gains	SAP (69)	W	1,150.91	1,107.04	1,028.92	985.37	731.00	1,227.70	922.62
Mean Int. Temperature / Degree Days:									
Mean Int. Temperature	SAP (77)	°C	17.58		17.57	18.10	18.55	17.16	17.35
Degree Days	SAP (80)		1,795.04		1,769.28	1,705.39	1,564.52	1,830.15	1,843.14
Space and Water Heating:									
Fuel Type			gas		gas		gas	gas	gas
Boiler			pre 98		pre 98		pre 98	pre 98	pre 98
Efficiency		%	65%		65%		65%	65%	65%
Primary Pipework			uninsulated		uninsulated		uninsulated	uninsulated	uninsulated
Controls			stat, prgm, no valves		stat, prgm, no valves		, prgm, no valves	, prgm, no valves	, prgm, no valves
Flue Type			balanced / open		balanced / open		balanced / open	balanced / open	balanced / open
Pump Location			in heated space		in heated space		in htd space	in htd space	in htd space
Water Heating Tank Size		litre	110 litre		110 litre		80 litre	110 litre	110 litre
Insulation		mm	foam, 38mm		foam, 38mm		foam, 38mm	foam, 38mm	foam, 38mm
Secondary Heating			none		none		none	none	none
Output Water Heating	SAP (51)	kWh/yr	4,112.98		3,960.06		3,563.00	4,334.73	3,771.21
Space Heating Req'ments	SAP (81)	kWh/yr	17,669.23	13,544.76	12,076.10	9,094.97	4,967.47	18,266.35	13,221.72
Energy Requirements (Delivered) and Fuel Costs:									
Space Heating - Gas	SAP (85)+(85a)	kWh/yr	29,448.71	22,790.24	20,126.83	15,158.28	8,279.12	30,443.91	22,036.20
	SAP (88)+(89)	£/yr	480.01	371.48	328.07	247.08	134.95	496.24	359.19
Water Heating - Gas	SAP (86a)	kWh/yr	6,854.96	6,854.96	6,600.11	6,600.11	5,938.33	7,224.55	6,285.35
	SAP (91b)	£/yr	111.74	111.74	107.58	107.58	96.79	117.76	102.45
Electricity	SAP (87)+Lighting	kWh/yr	925.65	934.55	835.17	839.39	740.49	1,076.14	703.72
(lighting, fans, pumps)	SAP (92)+(93)	£/yr	65.65	66.54	59.47	59.77	52.73	76.63	52.03
Standing Charges	SAP (94)	£/yr	34.00	34.00	34.00	34.00	34.00	34.00	34.00
Total Energy		kWh/yr	**37,229.32**	**30,579.75**	**27,562.11**	**22,597.78**	**14,957.94**	**38,744.60**	**29,025.27**
	SAP (97)	£/yr	**691.40**	**583.76**	**529.12**	**448.43**	**318.47**	**724.63**	**547.67**
SAP Results:									
SAP Energy Cost		£	692.00	584.00	529.00	448.00	318.00	725.00	548.00
CO_2 Emissions		t/yr	7.43	6.15	5.54	4.58	3.07	7.76	5.80
Primary Energy used		kWh/m^2/yr	498.00	412.00	419.00	346.00	302.00	445.00	517.00
TER			22.69	22.69	20.82	20.82	25.12	23.46	28.27
DER			85.99	70.97	71.33	58.76	52.96	76.57	88.63
Improvement		%	-279	-213	-243	-182	-111	-226	-214
SAP Rating	**SAP Rating**		**39**	**48**	**49**	**57**	**66**	**42**	**43**
EI Rating	**Carbon Savings**		**34**	**42**	**43**	**51**	**61**	**37**	**37**

Appendix 2: SAP calculation results for refurbished dwelling types

Refurbished Housing Stock in Great Britain, 2001							
Dwelling Type		Units	**Semi-Detached**	**Mid Terrace**	**Flat**	**Detached**	**Bungalow**
Total Number:							
% of 100% (=24,422,000)	Total = 24,422,000	%	28.4%	27.7%	18.9%	16.2%	8.4%
(1,000s)	Total = 24,422,000	(1,000s)	6,936.00	6,766.00	4,639.00	3,956.00	2,051.00
Building Details:							
Age			all	all	1960	after 1930	1945
Location			Sheffield	Sheffield	Sheffield	Sheffield	Sheffield
Shelter - Exposure			2	2	4	2	2
Household Occupants			3	2-3	2	3	2
Total Area		m^2	89.00	79.00	61.00	104.00	67.00
Plan Aspect Ratio 1.4	Width	m	5.64	5.31	6.60	6.09	6.92
	Depth	m	7.89	7.44	9.24	8.53	9.69
Building Perimeter		m	19.50	10.00	13.20	42.00	33.20
Number of Storeys			2	2	1	2	1
Storey Height	Ground Floor	m	2.40	2.40	2.40	2.40	2.40
	First Floor	m	2.60	2.60	0	2.60	0
Ventilation:							
Draught Lobby			no	no	yes	no	no
Draught Proofing		%	100%	100%	100%	100%	100%
Pressure Test @ 50Pa			5 $m^3/(hm^2)$	5 $m^3/(hm^2)$	5 $m^3/(hm^2)$	5 $m^3/(hm^2)$	5 $m^3/(hm^2)$
Air Change Rate		ach	0.60	0.60	0.60	5.00	0.60
Thermal Bridging		W/m^2K	0.15	0.15	0.15	0.15	0.15
Ventilation System			mech extract	mech extract	natural	mech extract	mech extract
Vents	Chimneys		0	0	0	0	0
	Open Flues		0	0	0	0	0
	Fans / Vents		0	0	0	0	0
Effective Air Change Rate	SAP (25)	ach^{-1}	0.50	0.50	0.50	0.50	0.50
Heat Losses:							
Ground Floor	Area	m^2	44.50	39.50	0	52.00	67.00
	Living Area	m^2	26.70	23.70	0	26.00	33.50
	U-value	W/m^2K	0.25	0.25	0 / 0.10	0.25	0.25
Walls	Area (incl. openings)	m^2	97.50	50.00	31.68	210.00	79.68
	Wall Type		solid / cavity	solid / cavity	cavity	cavity	cavity
	U-value	W/m^2K	0.35	0.35	0.35	0.35	0.35
Roofs	Area	m^2	44.50	39.50	0	52.00	67.00
	Pitch Angle		35°	35°	0°	35°	35°
	Loft Insul. Thickness	mm	250-300mm	250-300mm	100-160mm	250-300mm	250-300mm
	U-value	W/m^2K	0.16	0.16	0 / 0.10	0.16	0.16
Windows	Area	m^2	17.00	16.00	7.00	19.00	13.80
	Glazing		double or triple	double or triple	double or triple	double or triple	double or triple
	U-value	W/m^2K	1.30	1.30	1.30	1.30	1.30
External Doors	Area	m^2	3.70	3.70	1.85	3.70	3.70
	U-value	W/m^2K	1.00	1.00	1.00	1.00	1.00
Heat Loss Coefficient	SAP (37)	W/K	134.52	102.21	80.06	172.05	128.57
Heat Loss Parameter (HLP)	SAP (38)	W/m^2K	1.51	1.29	1.31	1.65	1.92
Gains:							
Lighting	Number of LE Fittings		8 of 8	7 of 7	5 of 5	10 of 10	7 of 7
Internal Gains	SAP (55)	W	576.33	529.81	437.8	644.97	471.08
Solar Gains	SAP (65)	W	226.1	242.44	139.36	273.98	194.71
Useful Gains	SAP (69)	W	763.17	700.95	529.63	887.35	645.20
Internal Gains:							
Mean Int. Temperature	SAP (77)	°C	18.17	18.43	18.38	17.97	18.28
Degree Days	SAP (80)		1,449.24	1,255.48	1,295.77	1,517.94	1,617.58
Space and Water Heating:							
Fuel Type			gas	gas	gas	gas	gas
Boiler	SEDBUK Condensing		Cond., Band A Vaillant 615	Cond., Band A Vaillant 615	Combi, Band A Vaillant 831	Cond., Band A Vaillant 618	Cond., Band A Vaillant 618
Efficiency		%	91.20%	91.20%	91.10%	91.20%	91.20%
Primary Pipework			insulated	insulated	n/a	n/a	n/a
Controls			stat, prgm, trv	stat, prgm, trv	stat, prgm, trv	stat, prgm, trv	stat, prgm, trv
Flue Type			room-sealed	room-sealed	room-sealed	room-sealed	room-sealed
Pump Location			in htd space	in htd space	in htd space	in htd space	in htd space
Water Heating Tank Size		litre	110 litre	110 litre	n/a	n/a	n/a
Insulation		mm	foam, 80mm	foam, 80mm	n/a	n/a	n/a
Secondary Heating			none	none	none	none	none
Output Water Heating	SAP (51)	kWh/yr	2,909.61	2,756.70	2,471.22	3,131.36	2,522.00
Space Heating Req'ments	SAP (81)	kWh/yr	4,678.85	3,079.73	2,489.70	6,268.02	4,991.35
Energy Requirements (Delivered) and Fuel Costs:							
Space Heating - Gas	SAP (85)+(85a)	kWh/yr	5,113.50	3,365.83	2,732.93	6,850.30	5,455.02
	SAP (88)+(89)	£/yr	83.35	54.86	44.55	111.66	88.92
Water Heating - Gas	SAP (86a)	kWh/yr	3,179.90	3,012.78	2,712.65	3,422.26	2,756.29
	SAP (91b)	£/yr	51.83	49.11	44.22	55.78	44.93
Electricity	SAP (87)+Lighting	kWh/yr	803.20	728.86	632.06	913.20	637.35
(lighting, fans, pumps)	SAP (92)+(93)	£/yr	57.19	51.89	45.00	65.02	45.38
Standing Charges	SAP (94)	£/yr	34.00	34.00	34.00	34.00	34.00
Total Energy		kWh/yr	**9,096.60**	**7,107.47**	**6,077.64**	**11,185.76**	**8,848.66**
	SAP (97)	£/yr	**226.37**	**189.86**	**167.77**	**266.46**	**213.23**
SAP Results:							
SAP Energy Cost		£	226.00	190.00	168.00	266.00	213.00
CO_2 Emissions		t/yr	1.95	1.55	1.32	2.80	1.86
Primary Energy used		$kWh/m^2/yr$	132.00	119.00	132.00	138.00	168.00
TER			22.69	20.82	25.12	23.46	28.27
DER			24.08	21.73	24.64	25.30	30.44
Improvement		%	-6	-4	2	-8	-8
SAP Rating	**SAP Rating**		**82**	**84**	**84**	**80**	**80**
EI Rating	**Carbon Savings**		**81**	**83**	**83**	**79**	**78**

Appendix 3: SAP calculation results for new build dwelling types

New Housing Stock in Great Britain, 2001							
Dwelling Type		Units	Semi-Detached	Mid Terrace	Flat	Detached	Bungalow
Total Number:							
% of 100% (=24,422,000)							
(1,000s)							
Building Details:							
Age			2010	2010	2010	2010	2010
Location			Sheffield	Sheffield	Sheffield	Sheffield	Sheffield
Shelter - Exposure			2	2	4	2	2
Household Occupants			2	2-3	2	3	2
Total Area		m^2	89.00	79.00	61.00	104.00	67.00
Plan Aspect Ratio 1.4	W x D	m	5.64	5.31	6.60	6.09	6.92
	W x D	m	7.89	7.44	9.24	8.53	9.69
Building Perimeter		m	19.50	10.00	13.20	42.00	34.2
Number of Storeys			2	2	1	2	1
Storey Height	Ground Floor	m	2.40	2.40	2.40	2.40	2.40
	First Floor	m	2.60	2.60	0	2.60	0
Ventilation:							
Draught Lobby			yes	yes	yes	yes	yes
Draught Proofing		%	100%	100%	100%	100%	100%
Pressure Test @ 50Pa			3 $m^3/(hm^2)$	3 $m^3/(hm^2)$	3 $m^3/(hm^2)$	3 $m^3/(hm^2)$	3 $m^3/(hm^2)$
Air Change Rate		ach	0.50	0.50	0.50	0.50	0.50
Thermal Bridging		W/m^2K	0.08	0.08	0.08	0.08	0.08
Ventilation System			MVHR	MVHR	MVHR	MVHR	MVHR
Vents	Chimneys		0	0	0	0	0
	Open Flues		0	0	0	0	0
	Fans / Vents		0	0	0	0	0
Effective Air Change Rate	SAP (25)	ach^{-1}	0.30	0.30	0.28	0.30	0.30
Heat Losses:							
Ground Floor	Area	m^2	44.50	39.50	0	52.00	67.00
	Living Area	m^2	26.70	23.70	0	26.00	33.5
	U-value	W/m^2K	0.20	0.20	0 / 0.10	0.20	0.20
Walls	Area (incl. openings)	m^2	97.50	50.00	31.68	210.00	82.08
	Wall Type		cavity	cavity	cavity	cavity	cavity
	U-value	W/m^2K	0.20	0.20	0.20	0.20	0.20
Roofs	Area	m^2	44.50	39.50	0	52.00	67.00
	Pitch Angle		35º	35º	0º	35º	35º
	Loft Insul. Thickness	mm	300mm	300mm	100-160mm	300mm	300mm
	U-value	W/m^2K	0.10	1.10	0 / 0.10	0.10	1.10
Windows	Area	m^2	17.00	16.00	7.00	19.00	13.80
	Glazing		double or triple	double or triple	double or triple	double or triple	double or triple
	U-value	W/m^2K	1.30	1.30	1.30	1.30	1.30
External Doors	Area	m^2	3.70	3.70	1.85	3.70	3.70
	U-value	W/m^2K	1.00	1.00	1.00	1.00	1.00
Heat Loss Coefficient	SAP (37)	W/K	90.18	71.09	54.06	112.96	86.17
Heat Loss Parameter (HLP)	SAP (38)	W/m^2K	1.01	0.90	0.89	1.09	1.29
Gains:							
Lighting	Number of LE Fittings		8 of 8	7 of 7	5 of 5	10 of 10	7 of 7
Internal Gains	SAP (55)	W	603.03	553.51	453.29	676.17	490.38
Solar Gains	SAP (65)	W	226.1	242.44	139.36	273.98	194.71
Useful Gains	SAP (69)	W	712.08	636.48	477.89	838.36	613.89
Internal Gains:							
Mean Int. Temperature	SAP (77)	ºC	18.43	18.65	18.86	18.50	18.58
Degree Days	SAP (80)		1,051.64	894.66	953.89	1,155.00	1,231.41
Space and Water Heating:							
Fuel Type			gas	gas	gas	gas	gas
Boiler	SEDBUK Condensing		Combi, Band A Vaillant 937	Combi, Band A Vaillant 937	Combi, Band A Vaillant 937	Combi, Band A Vaillant 937	Combi, Band A Vaillant 937
Efficiency		%	91.50%	91.50%	91.50%	91.50%	91.50%
Primary Pipework			insulated	insulated	insulated	insulated	insulated
Controls			time, temp zone	time, temp zone	time, temp zone	time, temp zone	time, temp zone
Flue Type			room-sealed	room-sealed	room-sealed	room-sealed	room-sealed
Pump Location			in htd space	in htd space	in htd space	in htd space	in htd space
Water Heating Tank Size		litre	n/a	n/a	n/a	n/a	n/a
Insulation		mm	n/a	n/a	n/a	n/a	n/a
Secondary Heating			none	none	none	none	none
Output Water Heating	SAP (51)	kWh/yr	2,909.61	2,756.00	2,398.26	3,131.36	2,522.00
Space Heating Req'ments	SAP (81)	kWh/yr	2,276.13	1,526.47	1,237.52	3,131.37	2,546.66
Energy Requirements (Delivered) and Fuel Costs:							
Space Heating - Gas	SAP (85)+(85a)	kWh/yr	2,487.57	1,668.27	1,352.48	3,422.26	2,783.23
	SAP (88)+(89)	£/yr	44.55	27.19	22.05	55.78	45.37
Water Heating - Gas	SAP (86a)	kWh/yr	3,179.90	3,012.78	2,621.05	3,422.26	2,756.29
	SAP (91b)	£/yr	51.83	49.11	42.72	55.78	44.93
Electricity	SAP (87)+Lighting	kWh/yr	1,128.94	1,018.00	846.39	1,293.84	872.76
(lighting, fans, pumps)	SAP (92)+(93)	£/yr	80.38	72.48	60.26	92.12	62.15
Standing Charges	SAP (94)	£/yr	34.00	34.00	34.00	34.00	34.00
Total Energy		kWh/yr	**6,796.41**	**5,699.05**	**4,819.92**	**8,138.36**	**6,412.28**
	SAP (97)	£/yr	**210.76**	**182.78**	**159.03**	**237.68**	**186.45**
SAP Results:							
SAP Energy Cost		£	207.00	183.00	159.00	238.00	186.00
CO_2 Emissions		t/yr	1.58	1.34	1.13	1.87	1.44
Primary Energy used		$kWh/m^2/yr$	109.00	104.00	114.00	111.00	132.00
TER			22.69	20.82	25.12	23.46	28.27
DER			19.43	18.69	20.80	19.89	23.50
Improvement		%	14	10	17	15	17
SAP Rating	**SAP Rating**		**84**	**85**	**85**	**83**	**83**
EI Rating	**Carbon Savings**		**84**	**86**	**86**	**83**	**83**

Appendix 4: Typical SAP calculation printout using Elmhurst SAP Software v.13

Full SAP Calculation Printout

Users Ref: SD_C_Ref

Issued on: 1.July.2008
Prop Type Ref:

Property: Semi-Detached_Cav_Refurb, Sheffield, S1 2JA

TER: 22.69
DER: 24.08

SAP Rating: 82 B | **SAP Energy Cost:** £226 | **CO2 Emissions:** 1.95 t/year
EI Rating: 81 B | **Energy used:** 132 kWh/year

Surveyor: 0000-0000, Unaccredited Surveyor
Address:
Client:

Software Version: EES SAP 2005.013.build.0013, January 2008 (Design System), BRE SAP Worksheet 9.80
Regs Type: SAP 2005, Regs Region: England and Wales (Part L1A 2006), Construction Type: New Build

CALCULATION DETAILS for survey reference no 'SD_C_Ref' Page: 1

SAP2005 Input data (DesignData) -

```
Regs Region:                    England
Construction Type:              NewBuild
Region:                         MI Midlands (15.5)
Orientation:                    Unknown
PropType:                       H  House, S  Semi Detached
Storeys:                        2
Property Age:                   2010
Sheltered Sides:                2
Sunlight Shade:                 Average or unknown
Wall Perimeter:                 19.50 m, 19.50 m
Floor Area:                     44.50 m2, 44.50 m2
Living Floor Area:              26.70 m2
Storey Height:                  2.40 m, 2.60 m
Doors
    Door 1:                     Solid Wood, uvalue: 1.00 (M), area: 3.70 m2
Windows
    Window N:                   Triple,Low E,Soft Coat, Wood, 16 mm, South (180Â°), uvalue: 1.30
    Window S:                   Triple,Low E,Soft Coat, Wood, 16 mm, North (0Â°), uvalue: 1.30 (T
    Window E:                   Triple,Low E,Soft Coat, Wood, 16 mm, West (90Â°), uvalue: 1.30 (T
Draught Lobby:                  No
Draught Proofing:               100%
Roof Lights
Pressure Test:                  5.00
Mechanical Ventilation:         Mechanical extract ventilation, Manufacturer air change rate: 0.6
Fans, Chimneys, Flues:          0, 0, 0
Lighting:                       Low energy lighting in all fixed outlets
Main Wall Type:                 U: 0.35 A: X(76.80 m2)
Extented Wall Types:
Timber Frame Wall Area:         0.00
Roof type 0
Roof Roof 1                     U: 0.16 A: 44.50 m2
Main Floor Type:                U: 0.25 A: 44.50 m2
Timber Floor:                   No Timber Floor
Thermal Mass:                   Simple Thermal Mass Parameter calculation:
                                Ground Floor Mass: Medium - solid floor
                                External Wall Mass: Low - timber/steel frame walls or masonry wal
                                Separating Wall Mass: Medium - masonry walls with plasterboard on
                                Internal Partition Mass: Low - plasterboard on timber/steel stud
Main Heating:                   BGB Post 98 Gas condens. (incl combis) with auto ign. F.A.F., Pum
Main Heating Manufacturer:      Vaillant, ecoTEC plus 937, 91.50%
Heating Controls:               CBD Programmer, room thermostat and TRVs
Underfloor Heating:             None
Combi Type:                     StandardCombi
Combi Keep Hot:                 WithoutKeepHot
Secondary Heating:              None
Thermal Store:                  None
```

Hot Water Heating:	HWP From the primary heating system
Hot Water Cylinder:	None
Solar Water Heating:	None
Electricity Tariff:	S - Standard
PV Cells:	None
Thermal Bridges:	DefaultNoRobustConstr, Thermal bridging factor y = 0.15
Energy Saved:	
Energy Used:	

CALCULATION DETAILS for survey reference no 'SD_C_Ref'	Page: 3

SAP calculation (Existing Dwelling as Designed)

1. Overall house dimensions			
Ground floor	44.500 * 2.400	106.80	
First floor	44.500 * 2.600	115.70	
Total floor area	89.000		(5)
Total house volume		222.50	(6)
2. Ventilation rate			
Number of chimneys	0 * 40	0	
Number of flues	0 * 20	0	
Number of fans	0 * 10	0	
Flueless gas fire	0 * 40	0	
Infiltration		0.00	(10)
Pressure test value		5.00	(q50)
Infiltration rate		0.25	(19)
Sides sheltered		2	(20)
Shelter factor		0.85	(21)
Adjusted infiltration rate		0.21	(22)
Air change Extract ventilation		0.50	(23b)
Effective air change rate		0.50	(25)
3. Heat losses			
Doors Door 1	3.700 * 1.000	3.70	
Doors Heat Loss total		3.70	(26)
Windows Window N	6.800 * 1/[(1/ 1.300)+0.04]	8.40	
Windows Window S	8.500 * 1/[(1/ 1.300)+0.04]	10.50	
Windows Window E	1.700 * 1/[(1/ 1.300)+0.04]	2.10	
Windows Heat Loss total		21.01	(27)
Roof Lights Heat Loss total		0.00	(27)
Floor 1	44.500 * 0.250	11.13	
Ground floor Heat Loss total		11.13	(28)
Main External wall type	76.800 * 0.350	26.88	(29)
Secondary walls Loss total		0.00	(29a)
Roof Roof 1	44.500 * 0.160	7.12	(30)
Roof Loss total		7.12	(30)
Total area of elements		186.50	(32)
Fabric heat loss		69.83	(33)
Appendix K: Thermal bridging		0.15	(y)
Effect of thermal bridges		27.98	(34)
Total fabric heat loss		97.81	(35)
Ventilation heat loss		36.71	(36)
Heat loss coefficient		134.52	(37)
Heat loss parameter (HLP)		1.51	(38)
4. Water heating energy requirements			
Energy of heated water		1963.17	(39)
Distribution loss		346.44	(40)
Hot Water storage loss factor		0.0000	(44)
Volume factor		0.000	(44a)
Temperature factor T		1.00	(44b)
Energy lost from tank		0.00	(45)
Energy lost from tank		0.00	(46)
If cyl contains solar storage		0.00	(47)
Primary circuit loss		0.00	(48)

Combi loss from Table 3a	600.00	(49)
Output from water heater	2909.61	(51)
Gains from water heating	917.95	(52)

5. Internal gains

Lighting, appliances, cooking and metabolic (Table 5)	523.20	(53)
Reduction of internal gains due to LE lighting (Appendix L)		
Correction factor for low-energy outlets	0.50	(C1)
Window 1 0.9 * 6.800 * 0.70 * 0.7 * 0.83 / 89.000	0.03	
Window 2 0.9 * 8.500 * 0.70 * 0.7 * 0.83 / 89.000	0.03	
Window 3 0.9 * 1.700 * 0.70 * 0.7 * 0.83 / 89.000	0.01	
Ratio of glass area to floor area	0.07	(GL)
Correction factor for daylighting	0.99	(C2)
Annual energy used for lighting in the house	411.04	(EL)
Reduction in lighting use due to low energy lights	411.04	(deltaEL)
Low energy lighting	-61.66	(53a)
Central heating pump	10.00	(53b)
Water heating	104.79	(54)
Total internal gains	576.33	(55)

6. Solar gains

	Access Factor	Area (m2)	Flux	g	FF	Gains (W)	
Windows 'S '	0.770 *	6.800 *	72.000 * 0.9 *	0.570	* 0.7	135.38	(60)
Windows1 'N '	0.770 *	8.500 *	29.000 * 0.9 *	0.570	* 0.7	68.16	(56)
Windows2 'W '	0.770 *	1.700 *	48.000 * 0.9 *	0.570	* 0.7	22.56	(62)

Total solar gains	226.10	(65)
Total gains, W	802.43	(66)
Gains/loss ratio (GLR)	5.97	(67)
Utilisation factor	0.951	(68)
Useful gains, W	763.17	(69)

7. Mean internal temperature

Mean internal temperature of living zone (heating type = 1)	18.88	(70)
Temperature addjustment	0.00	(71)
Adjustment for gains	0.33	(72)
Adjusted room temperature	19.21	(73)
Temperature difference between zones	1.49	(74)
Living area fraction	0.300	(75)
Rest of house floor fraction	0.700	(76)
Mean internal temperature	18.17	(77)

8. Degree days

Temperature raise from gains	5.67	(78)
Base temperature	12.50	(79)
Degree days	1449.24	(80)

9a. Energy requirements - individual heating systems, including micro-CHP

Space heating requirement (useful)	4678.85	(81)
Database boiler reference number : 15429		
Model name : ecoTEC plus 937		
Manufacturer: Vaillant		
MHS efficiency	91.5	
Main system efficiency	91.5	(83)
Secondary system efficiency	0.0	(84)
Space heating fuel - main HS	5113.50	(85)
Space heating fuel - secondary HS	0.00	(85a)
Efficiency of water heater	91.50	(86) (from SED
Energy required for water heating	2909.61	
Energy used for water heating	3179.90	(86a)
For each central heating pump	130.00	(87a)
For each boiler with F.A.F	45.00	(87b)
For mechanical ventilation	217.16	(87d)
Electricity for pumps, fans, ...	392.16	(87)

CALCULATION DETAILS for survey reference no 'SD_C_Ref'			Page: 5
10a. Fuel costs - individual heating systems			
MHS heating cost	[5113.50 * 1.6300 * 0.01]	83.35	(88)
SHS heating cost	[0.00 * 0.0000 * 0.01]	0.00	(89)
Water heating cost	[3179.90 * 1.6300 * 0.01]	51.83	(91)
Pump/fan energy	[392.16 * 7.1200 * 0.01]	27.92	(92)
Lighting energy	[411.04 * 7.1200 * 0.01]	29.27	(93)
Additional standing charges		34.00	(94)
Total energy cost		226.37	(97)
Total energy cost using Sedbuk db prices		347.99	
11. SAP rating			
Energy cost deflator		0.91	(98)
Energy cost factor		1.31	(99)
ECF unrounded = 1.31340800919036			
SAP value		81.66	
SAP value unrounded = 81.6648241917025			
SAP Energy rating		82	(100)
SAP Energy rating band		B	
12a. Carbon dioxide emissions			
MHS heating CO2	[5113.50 * 0.1940]	992.02	(101)
WHS heating CO2	[3179.90 * 0.1940]	616.90	(103)
Space and water heating CO2		1608.92	(107)
Pumps and fans CO2	[392.16 * 0.4220]	165.49	(108)
Lighting CO2	[411.04 * 0.4220]	173.46	(109)
Total CO2 emissions in kg/year		1947.87	(112)
Dwelling's Carbon Factor		14.54	(CF)
Environmental Impact Rating		80.52	
Environmental Impact Rating rounded		81	
Environmental Impact Rating band		B	
13a. Primary energy			
MHS heating P.E.	[5113.50 * 1.1500]	5880.52	
WHS heating P.E.	[3179.90 * 1.1500]	3656.89	
Space and water heating P.E.		9537.41	
Pumps and fans P.E.	[392.16 * 2.8000]	1098.05	(104)
Lighting P.E.	[411.04 * 2.8000]	1150.90	(104a)
Primary energy kWh/year		11786.36	
Primary energy kWh/m2/year		132.43	(105)

Appendix 5: Limiting criteria of the calculation models

1.	All five models above look at the average of the total housing stock in Great Britain (GB). Northern Ireland is not included because information was not consistently available in the researched documents. Variations in cost, which are approximately 10% lower in Northern Ireland than the average GB house, made it more difficult to compare data.
2.	The collected data on the housing stock is based on 2001 results, because this year coincidently produced the most coherent data in research documents. Some of the information has changed in the last seven years but it is marginal when considered over an overall time span.
3.	The models representing an average for GB housing, therefore many figures are generic assumptions. However, it is self-explanatory, because homes do come in a large variety of types and sizes, therefore when considered on an individual basis the modelled results may differ greatly from individual cases.
4.	It is acknowledged that not all dwellings are able to be refurbished. Listed Buildings and building within Conservation Areas will more than likely be limited by some, if not all, of the energy-saving measures. This constraint realistically only represents approximately 2% of all homes, therefore it is safe to exclude them from the stock calculation for refurbishments without drastically disfiguring the results.
5.	Flats are difficult to evaluate for cost of measures, because more than likely ownership is shared by many parties, including Local Authorities. This can play a major part in influencing decisions to refurbish enormously. Also, individual owners may find it difficult to refurbish their flat, because it requires the consent of other owners or tenants and it requires the economies of scale to reduce costs.
6.	The model assumes that new build homes are based on the same brief as existing homes. The dissertation has to assume the land does not have to be purchased, because this would dramatically affect capital cost. Land values can vary enormously from one location to the next; for instance rural land is often much cheaper per square foot than urban land.
7.	The SAP programme is based on fuel costs from 2005 and does not reflect current increases in market values (e.g. gas = 1.63 p/kWh). The payback calculation is adjusted to today's unit price for gas (British Gas: 2.85 p/kWh) to obtain the true value of energy-efficiency measures.
8.	Energy expenditure costs has been normalised in the SAP programme by floor area, in order to compare the rating of a small dwelling with a large one. Albeit, large dwellings are a lot more inefficient than smaller dwellings, hence it is easier to make larger properties more energy efficient.
9.	SAP does not take into account household size, composition or ownership. Water use or energy use from appliances are not included either. They are normally important parameters in the assessment of total energy consumption from dwellings, but they are based on occupant behaviour, which always varies. For this study, default values in SAP are used which are based on the floor area of the dwelling.
10.	The calculations are based on today's values (August 2008) for capital and fuel costs and interest rates; which will inevitably change in the future. Therefore, the results provide a useful indication of the current situation, but obviously will need to be revised over time to revaluate future cost-effectiveness.
11.	None of the predictions for 2050 take into account improvements in technology, especially costs and performance efficiency of renewables. The future should (positively) alter the results considering the achievements that have been made in the last 40 years.

Appendix 6: Cost and energy savings for refurbishment measures by dwelling type

Refurbished Semi-Detached Total Area: 89 m²			SAP Increase (points)	EI Increase (points)	Primary Energy (kWh/m²/yr)	Carbon Savings (tC/yr)	COST (Interest Rate 7%) Capital Cost (Installed) (£)	Investment Time (yrs)	Lifetime Measure (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	BENEFITS Annual Savings (£/yr)	TOTAL Annual Savings (£/yr)	Payback Period (yrs)	Pound / Carbon (£/tC)
Measure	Before Refurbishment		48	42	410	6.10									
	After Refurbishment - Solid		43	47	366.00	5.48									
	After Refurbishment - Cavity		34	39	280.00	4.20									
Insulation	Internal	85mm	12	12	98	1.46	4,100.00	10.0	50	-583.75	5,837.48	225.70	-358.05	25.9	56.16
	External	100mm	12	12	102	1.52	6,825.00	12.0	50	-859.28	10,311.37	236.80	-622.48	43.5	89.80
	Cavity	50mm	10	10	83	1.23	510.00	2.0	50	-282.08	564.15	192.40	-89.68	2.9	8.29
	Floor	Susp. Timber, 100r	3	3	22	0.32	100.00	1.0	50	-107.00	107.00	49.95	-57.05	2.1	6.25
	Roof / Loft	Pitched, 250mm	2	2	12	0.17	500.00	2.0	50	-276.55	553.09	25.90	-250.65	21.4	58.82
	Windows	double / triple	2	2	20	0.29	5,100.00	15.0	40	-559.95	8,399.29	44.40	-515.55	189.2	439.66
	Doors	1.0 W/m²K	1	1	8	0.11	600.00	2.0	40	-331.86	663.71	18.50	-313.36	35.9	136.36
Ventilation	Draught Proofing	100%, 5 m³/(hm²)	3	3	22	0.32	200.00	2.0	30	-110.62	221.24	49.95	-60.67	4.4	20.83
	Mechanical Extract		-1	0	-7	-0.11	350.00	2.0	15	-193.58	387.16	-72.15	-265.73	-5.4	-212.12
Space Heating	Boiler	A-rated	14	14	114	1.71	2,500.00	5.0	15	-609.73	3,048.63	262.70	-347.03	11.6	97.47
	Controls Upgrade	stats, prgm,TRVs	6	6	50	0.75	200.00	2.0	15	-110.62	221.24	116.55	5.93	1.9	17.78
Water Heating	Insulation Tank	80mm	1	1	3	0.04	12.00	0.5	15	-25.25	12.63	5.55	-19.70	2.3	20.00
	Insulation Pipes		1	1	8	0.11	10.00	0.5	15	-21.04	10.52	18.50	-2.54	0.6	6.06
Lighting	LE Lighting	8	2	1	7	0.08	20.00	0.5	10	-42.09	21.04	38.85	-3.24	0.5	25.00
TOTAL	Suitable measures - solid		+ 17.5% VAT				19,889.23								3,629.42
TOTAL	Suitable measures - cavity		+ 17.5% VAT				16,687.35								3,973.18

Semi-detached house

Refurbished Mid-Terrace Total Area: 79 m²			SAP Increase (points)	EI Increase (points)	Primary Energy (kWh/m²/yr)	Carbon Savings (tC/yr)	COST (Interest Rate 7%) Capital Cost (Installed) (£)	Investment Time (yrs)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	BENEFITS Annual Savings (£/yr)	TOTAL Annual Savings (£/yr)	Payback Period (yrs)	Pound / Carbon (£/tC)
Measure	Before Refurbishment		57	51	346	4.58									
	After Refurbishment - Solid		35	40	300.00	3.99									
	After Refurbishment - Cavity		27	32	227.00	3.03									
Insulation	Internal	85mm	6	6	44	0.6	2,100.00	5.0	50	-512.17	2,560.85	92.50	-419.67	27.7	70.00
	External	100mm	6	6	46	0.63	3,500.00	7.0	50	-649.44	4,546.05	96.20	-553.24	47.3	111.11
	Cavity	50mm	5	5	38	0.51	260.00	2.0	50	-143.80	287.61	77.70	-66.10	3.7	10.20
	Floor	Susp. Timber, 100r	3	3	22	0.31	90.00	1.0	50	-96.30	96.30	46.25	-50.05	2.1	5.81
	Roof / Loft	Pitched, 250mm	2	2	12	0.17	445.00	2.0	50	-246.13	492.25	24.05	-222.08	20.5	52.35
	Windows	double / triple	3	3	24	0.33	4,800.00	15.0	40	-527.01	7,905.21	49.95	-477.06	158.3	363.64
	Doors	1.0 W/m²K	2	1	9	0.13	600.00	2.0	40	-331.86	663.71	18.50	-313.36	35.9	115.38
Ventilation	Draught Proofing	100%, 5 m³/(hm²)	3	3	24	0.33	200.00	2.0	30	-110.62	221.24	49.95	-60.67	4.4	20.20
	Mechanical Extract		-1	0	-6	-0.08	350.00	2.0	15	-193.58	387.16	-24.05	-217.63	-16.1	-291.67
Space Heating	Boiler	A-rated	11	13	94	1.27	2,500.00	5.0	15	-609.73	3,048.63	192.40	-417.33	15.8	131.23
	Controls Upgrade	stats, prgm,TRVs	6	6	47	0.63	200.00	2.0	15	-110.62	221.24	96.20	-14.42	2.3	21.16
Water Heating	Insulation Tank	80mm	1	1	3	0.05	12.00	0.5	15	-25.25	12.63	5.55	-19.70	2.3	16.00
	Insulation Pipes		2	1	9	0.13	10.00	0.5	15	-21.04	10.52	18.50	-2.54	0.6	5.13
Lighting	LE Lighting	8	2	1	7	0.09	20.00	0.5	10	-42.09	21.04	35.15	-6.94	0.6	22.22
TOTAL	Suitable measures - solid		+ 17.5% VAT				15,259.73								3,824.49
TOTAL	Suitable measures - cavity		+ 17.5% VAT				13,614.73								4,493.31

Mid terrace house

Refurbished Flat Total Area: 61 m²			SAP Increase (points)	EI Increase (points)	Primary Energy (kWh/m²/yr)	Carbon Savings (tC/yr)	COST (Interest Rate 7%) Capital Cost (Installed) (£)	Investment Time (yrs)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	BENEFITS Annual Savings (£/yr)	TOTAL Annual Savings (£/yr)	Payback Period (yrs)	Pound / Carbon (£/tC)
Measure	Before Refurbishment		66	61	302	3.07									
	After Refurbishment		18	22	170.00	1.75									
Insulation	Internal	85mm	5	7	52	0.53	610.00	2.0	50	-337.39	674.77	81.40	-255.99	8.3	23.02
	External	100mm	5	7	54	0.55	1,010.00	5.0	50	-246.33	1231.65	85.10	-161.23	14.5	36.73
	Cavity	50mm	4	6	44	0.46	75.00	1.0	50	-80.25	80.25	70.30	-9.95	1.1	3.26
	Floor	Susp. Timber, 100r	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Roof / Loft	Pitched, 250mm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Windows	double / triple	1	2	12	0.13	2,700.00	10.0	40	-384.42	3844.19	18.50	-365.92	207.8	519.23
	Doors	1.0 W/m²K	0	1	6	0.06	300.00	2.0	40	-165.93	331.86	9.25	-156.68	35.9	125.00
Ventilation	Draught Proofing	100%, 5 m³/(hm²)	1	1	10	0.10	200.00	2.0	30	-110.62	221.24	14.80	-95.82	14.9	66.67
	Mechanical Extract		-3	-2	-36	-0.18	350.00	2.0	15	-193.58	387.16	-37.00	-230.58	-10.5	-129.63
Space Heating	Boiler	A-rated	10	13	96	0.99	2,500.00	5.0	15	-609.73	3048.63	149.85	-459.88	20.3	168.35
	Controls Upgrade	stats, prgm,TRVs	1	2	7	0.12	200.00	2.0	15	-110.62	221.24	16.65	-93.97	13.3	111.11
Water Heating	Insulation Tank	80mm	1	1	8	0.08	12.00	0.5	15	-25.25	12.63	12.95	-12.30	1.0	10.00
	Insulation Pipes		2	2	18	0.18	10.00	0.5	15	-21.04	10.52	27.75	6.71	0.4	3.70
Lighting	LE Lighting	8	2	1	1	0.08	20.00	0.5	10	-42.09	21.04	31.45	-10.64	0.7	25.00
TOTAL	Suitable measures - cavity		+ 17.5% VAT				8,197.98								4,684.56

Flat

Refurbished Detached Total Area: 104 m²			SAP increase (points)	EI increase (points)	Primary Energy (kWh/m²/yr)	Carbon Savings (tC/yr)	COST (Interest Rate 7%) Capital Cost (Installed) (£)	Investment Time (yrs)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	BENEFITS Annual Savings (£/yr)	TOTAL Annual Savings (£/yr)	Payback Period (yrs)	Pound / Carbon (£/tC)
Measure	Before Refurbishment		42	37	445	7.76									
	After Refurbishment		38	42	307	4.96									
Insulation	Internal	85mm	15	14	128	2.26	6,100.00	12.0	50	-768.00	9,216.03	351.50	-416.50	26.2	53.98
	External	100mm	16	15	134	2.36	10,220.00	15.0	50	-1122.10	16,831.52	368.15	-753.95	45.7	86.61
	Cavity	50mm	13	12	108	1.9	760.00	2.0	50	-420.35	840.70	296.00	-124.35	2.8	8.00
	Floor	Susp. Timber, 100	2	2	22	0.39	120.00	1.0	50	-128.40	128.40	61.05	-67.35	2.1	6.15
	Roof / Loft	Pitched, 250mm	1	1	10	0.18	580.00	2.0	50	-320.79	641.59	29.6	-291.19	21.7	64.44
	Windows	double / triple	2	1	16	0.29	5,700.00	16.0	40	-603.39	9,654.22	44.40	-558.99	217.4	491.38
	Doors	1.0 W/m²K	1	0	6	0.11	600.00	2.0	40	-331.86	663.71	18.50	-313.36	35.9	136.36
Ventilation	Draught Proofing	100%, 5 m³/(hm²)	2	2	19	0.33	200.00	2.0	30	-110.62	221.24	53.65	-56.97	4.1	20.20
	Mechanical Extract		-1	-1	-10	-0.16	350.00	2.0	15	-193.58	387.16	-40.70	-234.28	-9.5	-145.83
Space Heating	Boiler	A-rated	11	10	94	1.67	2,500.00	5.0	15	-609.73	3,048.63	257.15	-352.58	11.9	99.80
	Controls Upgrade	stats, prgm,TRVs	6	5	51	0.9	200.00	2.0	15	-110.62	221.24	140.60	29.98	1.6	14.81
Water Heating	Insulation Tank	80mm	0	0	2	0.04	12.00	0.5	15	-25.25	12.63	7.40	-17.85	1.7	20.00
	Insulation Pipes		1	1	6	0.11	10.00	0.5	15	-21.04	10.52	18.50	-2.54	0.6	6.06
Lighting	LE Lighting	8	2	0	6	0.09	20.00	0.5	10	-42.09	21.04	46.25	4.16	0.5	22.22
TOTAL	Suitable measures - cavity		+ 17.5% VAT				24,994.60								5,039.23

Detached house

Refurbished Bungalow Total Area: 67 m²			SAP increase (points)	EI increase (points)	Primary Energy (kWh/m²/yr)	Carbon Savings (tC/yr)	COST (Interest Rate 7%) Capital Cost (Installed) (£)	Investment Time (yrs)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	BENEFITS Annual Savings (£/yr)	TOTAL Annual Savings (£/yr)	Payback Period (yrs)	Pound / Carbon (£/tC)
Measure	Before Refurbishment		43	37	517	5.80									
	After Refurbishment		37	41	349	3.94									
Insulation	Internal	85mm	9	9	101	1.14	3,350.00	7.0	50	-621.60	4,351.22	177.60	-444.00	24.5	58.77
	External	100mm	10	10	106	1.19	5,580.00	10.0	50	-794.47	7,944.66	185.00	-609.47	42.9	93.78
	Cavity	50mm	8	8	86	0.96	415.00	2.0	50	-229.53	459.07	149.85	-79.68	3.1	8.65
	Floor	Susp. Timber, 100	3	4	42	0.46	150.00	1.0	50	-160.50	160.50	72.15	-88.35	2.2	6.52
	Roof / Loft	Pitched, 250mm	2	2	22	0.24	750.00	2.0	50	-414.82	829.64	38.85	-375.97	21.4	62.50
	Windows	double / triple	1	2	20	0.22	4,140.00	12.0	40	-521.23	6,254.81	35.15	-486.08	177.9	470.45
	Doors	1.0 W/m²K	1	1	10	0.11	600.00	2.0	40	-331.86	663.71	18.50	-313.36	35.9	136.36
Ventilation	Draught Proofing	100%, 5 m³/(hm²)	2	2	23	0.25	200.00	2.0	30	-110.62	221.24	40.70	-69.92	5.4	26.67
	Mechanical Extract		-1	0	-1	-0.10	350.00	2.0	15	-193.58	387.16	-11.10	-204.68	-34.9	-233.33
Space Heating	Boiler	A-rated	14	14	146	1.65	2,500.00	5.0	15	-609.73	3,048.63	253.45	-356.28	12.0	101.01
	Controls Upgrade	stats, prgm,TRVs	5	5	22	0.63	200.00	2.0	15	-110.62	221.24	98.05	-12.57	2.3	21.16
Water Heating	Insulation Tank	80mm	0	0	4	0.04	12.00	0.5	15	-25.25	12.63	7.40	-17.85	1.7	20.00
	Insulation Pipes		1	1	11	0.11	10.00	0.5	15	-21.04	10.52	18.50	-2.54	0.6	6.06
Lighting	LE Lighting	8	1	1	7	0.06	20.00	0.5	10	-42.09	21.04	29.60	-12.49	0.7	33.33
TOTAL	Suitable measures - cavity		+ 17.5% VAT				17,539.23								4,451.58

Bungalow

Appendix 7: Cost assumptions for improvement measures

	company	installed cost	annual saved cost (£)		
building components	for installed building components (incl. hourly rate, area, units etc)				Spon's architects' and builders' price book 2008 Davis Langdon Surveyors
external insulation	Wall Transform	70 £/m2			http://www.walltransform.co.uk/contacts.php (personal conversation)
	nat insul assoc	4500 total	380	ext render	http://www.nationalinsulationassociation.org.uk/housholder/householder-nia.html
	EST	4500 total	380		telephone conversation
internal insulation	nat insul assoc	42 £/m2	360-380	flex / rigid	http://www.nationalinsulationassociation.org.uk/housholder/householder-nia.html
	EST	42 £/m2	360		telephone conversation
cavity	nat insul assoc	500 total	120		http://www.nationalinsulationassociation.org.uk/housholder/householder-nia.html
	EST	500 total	120		telephone conversation
	Plymouth council	260 total		installed	http://www.plymouth.gov.uk/insulation#li
floor	EST	90 £		DIY	telephone conversation
	plymouth council	100 £		uninstalled	http://www.plymouth.gov.uk/insulation#li
loft	nat insul assoc	500 total	155	zero installed	http://www.nationalinsulationassociation.org.uk/housholder/householder-nia.html
	nat insul assoc	500 total	45	50mm install	http://www.nationalinsulationassociation.org.uk/housholder/householder-nia.html
	plymouth council	230 total		installed	http://www.plymouth.gov.uk/insulation#li
double glazing	Glas Facades Lim	950 £/m2		double glaze	http://www.bfrc.org/show_company.aspx?ID=9123
		300-400 £/m2			http://www.housebuildersupdate.co.uk/2007/06/everest-double-glazing-is-rip-off.html
	EST		110		telephone conversation
	what price	390 £/window			http://www.whatprice.co.uk/windows.html
	exist. Homes	£3,000		sealed	http://www.existinghomesalliance.org/media/83096-EnergyHeritage_online1.pdf
door	what price	400 £/door		installed	http://www.whatprice.co.uk/prices/building/door.html
	spon's	250-350 £/door		installed	spon's 2006
draught proofing	nat insul assoc	200 total	25		http://www.nationalinsulationassociation.org.uk/housholder/householder-nia.html
	EST	200 total	25		telephone conversation
	plymouth council	75 total			http://www.plymouth.gov.uk/insulation#li
mech extract	johnson&starley	220 £		uninstalled	http://www.buildingtalk.com/news/joh/joh000.html
cond boiler	urban solutions	2000 £			http://www.urbansolutions.co.uk/ (london price)
	guardian	2500 and up			http://www.guardian.co.uk/money/2005/apr/02/consumerissues.jobsandmoney
	whatprice	2260		incl £823 lab	http://www.whatprice.co.uk/plumbing/boiler.html
	mike the boilerma	800 - 3000		cheap boiler,	http://www.miketheboilerman.com/newboilercost.htm
	EST		130		telephone conversation
demolition	mgl demolition	£28/m2 ground fl £12/m2 first fl x4 for mid terrace and flats		total cost	personal conversation (Dan Holyoak)

Appendix 8: Payback time for doubled fuel prices for complete measures by dwelling type

Refurbished Semi-Detached		COST (Interest Rate 7%)				BENEFITS	TOTAL	
Total Area: 89 m²		Capital Cost (Installed) (£)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	Annual Savings (£/yr)	Annual Savings (£/yr)	Payback Period (yrs)
Semi-detached solid	fuel prices 2005	22,885.48	10	-£3,258.38	£32,583.77	661.17	-£2,597.21	49.3
	double of fuel prices 2005	22,885.48	10	-£3,258.38	£32,583.77	1322.34	-£1,936.03	24.6
Semi-detached cavity	fuel prices 2005	19,683.60	10	-£2,802.50	£28,025.02	728.72	-£2,073.79	38.5
	double of fuel prices 2005	19,683.60	10	-£2,802.50	£28,025.02	1457.43	-£1,345.07	19.2

Semi-detached house

Refurbished Mid Terrace		COST (Interest Rate 7%)				BENEFITS	TOTAL	
Total Area: 79 m²		Capital Cost (Installed) (£)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	Annual Savings (£/yr)	Annual Savings (£/yr)	Payback Period (yrs)
Mid-Terrace solid	fuel prices 2005	18,079.73	10	-£2,574.15	£25,741.47	627.63	-£1,946.52	41.0
	double of fuel prices 2005	18,079.73	10	-£2,574.15	£25,741.47	1255.26	-£1,318.88	20.5
Mid-Terrace cavity	fuel prices 2005	16,434.73	10	-£2,339.94	£23,399.36	478.35	-£1,861.58	48.9
	double of fuel prices 2005	16,434.73	10	-£2,339.94	£23,399.36	956.71	-£1,383.23	24.5

Mid terrace house

Refurbished Flat		COST (Interest Rate 7%)				BENEFITS	TOTAL	
Total Area: 61 m²		Capital Cost (Installed) (£)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	Annual Savings (£/yr)	Annual Savings (£/yr)	Payback Period (yrs)
Flat cavity	fuel prices 2005	9,784.23	10	-£1,393.05	£13,930.54	278.80	-£1,114.26	50.0
	double of fuel prices 2005	9,784.23	10	-£1,393.05	£13,930.54	557.59	-£835.46	25.0

Flat

Refurbished Detached		COST (Interest Rate 7%)				BENEFITS	TOTAL	
Total Area: 104 m²		Capital Cost (Installed) (£)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	Annual Savings (£/yr)	Annual Savings (£/yr)	Payback Period (yrs)
Detached cavity	fuel prices 2005	28,343.45	10	-£4,035.47	£40,354.70	847.61	-£3,187.86	47.6
	double of fuel prices 2005	28,343.45	10	-£4,035.47	£40,354.70	1695.23	-£2,340.24	23.8

Detached house

Refurbished Bungalow		COST (Interest Rate 7%)				BENEFITS	TOTAL	
Total Area: 67 m²		Capital Cost (Installed) (£)	Investment Lifetime (yrs)	Annuitised Capital (£/yr)	Real Capital Cost (£)	Annual Savings (£/yr)	Annual Savings (£/yr)	Payback Period (yrs)
Bungalow cavity	fuel prices 2005	19,971.48	10	-£2,843.49	£28,434.89	618.71	-£2,224.78	46.0
	double of fuel prices 2005	19,971.48	10	-£2,843.49	£28,434.89	1237.43	-£1,606.06	23.0

Bungalow

Appendix 9: Cost for new build dwellings

New Build - Cost				Semi-Detached	Mid-Terrace	Flat	Detached	Bungalow
Area			m^2	89.00	79.00	61.00	104.00	67.00
Capital Cost	Demolition Cost		£	2,100.00	7,450.00	6,830.00	2,450.00	2,205.00
	Construction	Materials, Builder etc	£	115,000	102,285	80,322	134,654	88,222
	Consultants	15% of Construction	£	17,250	15,343	12,048	20,198	13,233
	Services	2% of Construction	£	2,300	2,046	1,606	2,693	1,764
	TOTAL		£	**136,650**	**127,123**	**100,807**	**159,995**	**105,425**
Operational Cost	Gas		£/yr	96.38	76.30	64.77	111.56	90.30
	Electricity		£/yr	80.38	72.48	60.26	92.12	62.15
	Maintenance							
	TOTAL		£/yr	**176.76**	**148.78**	**125.03**	**203.68**	**152.45**

Appendix 10: Capital cost assumptions for new build dwellings

New build cost	floor area	greater london	south-east	nw, sw, east+scotland	mids, york, ne, wales	**average**	**total**
Semi-Detached	89	1,506	1,321	1,203	1,149	1,295	115,233
Mid Terrace	79	1,506	1,321	1,203	1,149	1,295	102,285
Flat	61	1,532	1,344	1,222	1,169	1,317	80,322
Detached	104	1,506	1,321	1,203	1,149	1,295	134,654
Bungalow	67	1,532	1,344	1,222	1,169	1,317	88,222

Source: BCIS Building Cost Information Service, 2008

Appendix 11: Primary energy use of dwellings

Primary Energy Use of Dwellings			**Operational Energy**			**Embodied Energy**		**Lifetime Energy (50 years)**	
			per m^2	per dwelling		per m^2	per dwelling	per m^2	per dwelling
Dwelling Type	Case	Size (m^2)	($kWh/m^2/yr$)	after 1 year (kWh)	after 50 years (kWh)	(kWh/m^2)	(kWh)	(kWh/m^2)	(kWh)
Semi-Detached	Existing		412	36,668	1,833,400	0	0	20,600	1,833,400
	Refurbished	89	132	11,748	587,400	170	15,130	6,770	602,530
	New [1]		101	8,989	449,450	1500	133,500	6,550	582,950
Mid-Terrace	Existing		346	27,334	1,366,700	0	0	17,300	1,366,700
	Refurbished	79	119	9,401	470,050	150	11,850	6,100	481,900
	New		101	7,979	398,950	1330	105,070	6,380	504,020
Flat	Existing		302	18,422	921,100	0	0	15,100	921,100
	Refurbished	61	132	8,052	402,600	100	6,100	6,700	408,700
	New		114	6,954	347,700	1030	62,830	6,730	410,530
Detached	Existing		445	46,280	2,314,000	0	0	22,250	2,314,000
	Refurbished	104	138	14,352	717,600	175	18,200	7,075	735,800
	New		111	11,544	577,200	1750	182,000	7,300	759,200
Bungalow	Existing		517	34,639	1,731,950	0	0	25,850	1,731,950
	Refurbished	67	168	11,256	562,800	110	7,370	8,510	570,170
	New		128	8,576	428,800	1130	75,710	7,530	504,510

[1] Primary embodied energy use for new build includes demolition and new construction.

Appendix 12: Comparison of refurbished and new build dwellings

Comparison of Refurbished and New Build			Semi-Detached		Mid-Terrace		Flat		Detached		Bungalow	
			Refurb	New	Refurb	New	Refurb	New	Refurb	New	Refurb	New
Area		m^2	89.00		79.00		61.00		104.00		67.00	
Cost	SAP Rating	points	82	84	84	85	84	85	80	83	80	83
	Capital	£	16,687	136,650	13,615	127,123	8,198	100,807	24,995	159,995	17,539	105,425
	Operational	£/yr	226	177	190	149	168	159	266	238	213	186
Energy Use	EI Rating	points	81	84	83	86	83	86	79	83	78	83
	Delivered	kWh/yr	9097	6796	7107	5699	6078	4820	11186	8138	8849	6412
	Gas	kWh/yr	8293	5667	6379	4681	5446	3974	10273	6845	8211	5540
	Electricity	kWh/yr	803	1129	729	1018	632	846	913	1294	637	873
	Primary (50yrs) [1]	kWh/m^2	602,530	582,950	481,900	504,020	408,700	410,530	735,800	759,200	570,170	504,510
Emissions	CO_2 Emissions	tCO_2/yr	1.95	1.58	1.55	1.34	1.32	1.13	2.80	1.87	1.86	1.44

[1] Primary energy is from operational and embodied energy use.

Appendix 13: Total energy requirements and savings of housing stock 2001 / 2050

Total Energy Requirements and Savings of Housing Stock in 2001 and 2050

		Dwellings 2001			Primary Energy Req'ments 2001			Dwellings 2050			Primary Energy Req'ments 2050			Savings over Existing by 2050		
	Dwelling Type	Total 1,000s	Type Wall	1,000s	Operational (PJ/yr)	Embodied (PJ)	Total Stock (PJ)	Total 1,000s	Type Wall	1,000s	Operational (PJ/yr)	Embodied (PJ)	Total Stock (PJ)	Energy (PJ)	Carbon [gas] (MtC)	Cost (m£/tonne)
Existing	Semi-Detached		Solid	1,734	276.68	0.00			Solid	180	28.72	0.00				
			Cavity	5,202	686.69	0.00			Cavity	535	70.62	0.00				
	Mid Terrace		Solid	1,692	201.62	0.00			Solid	175	20.85	0.00				
		24,422	Cavity	5,074	499.29	0.00	2,886.8	2,500	Cavity	520	51.17	0.00	296.5			
	Flat			4,639	307.65	0.00				475	31.50	0.00				
	Detached			3,956	659.10	0.00				405	67.48	0.00		1,009.5	14.8	4,570.9
	Bungalow			2,051	255.76	0.00				210	26.19	0.00				
Refurbished	Semi-Detached			0	0.00	0.00				5,410	228.80	294.67				
	Mid Terrace			0	0.00	0.00				5,280	178.69	225.24				
	Flat	0		0	0.00	0.00	0.0	19,000		3,620	104.93	79.50	1,580.7			
	Detached			0	0.00	0.00				3,080	159.13	201.80				
	Bungalow			0	0.00	0.00				1,610	65.24	42.72				
New Build	Semi-Detached			0	0.00	0.00				3,135	109.49	1,506.68				
	Mid Terrace			0	0.00	0.00				3,055	90.36	1,155.56				
	Flat	0		0	0.00	0.00	0.0	11,000		2,095	52.45	473.86	4,917.2	0.0	0.0	0.0
	Detached			0	0.00	0.00				1,790	74.39	1,172.81				
	Bungalow			0	0.00	0.00				925	29.45	252.11				